CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 58 JULY 1972 NUMBER 3

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CALIFORNIA FISH AND GAME

VOLUME 58 JULY 1972 NUMBER 3

Published Quarterly by
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

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Calif. Fish and Game, 58(3): 162–174. 1972.

LIFE HISTORY OF THE SAN JOAQUIN KIT FOX[1]

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A life history study of the San Joaquin kit fox, *Vulpes macrotis mutica*, was conducted from April, 1970 through June, 1971. The main study area was located near Taft, California, on the west side of the San Joaquin Valley. Twenty-eight kit foxes were trapped; 14 were tagged with small radio transmitters. Radio tagged kit foxes were located in different dens.

No specific hunting territories were maintained by individual foxes or family groups; family denning areas were apparent. Most adult foxes were solitary during the summer and early fall, and individuals were usually found in small dens. Pairing began in late fall, and the foxes remained paired while the young were raised. During the time they were paired and raised their pups, foxes usually occupied large dens.

Only one of the seven kit fox pairs consisted of the same foxes during two successive breeding seasons. One male kit fox apparently mated with three females. Kit foxes do not breed successfully their first year. Young are born in February or March, and the average litter size is four. Both parents hunt for food for the pups until the family group separates in the summer.

The average adult male and female kit foxes weigh approximately 5.0 lb. and 4.6 lb. respectively. The kit fox population density in the study area was six adults per square mile. The immediate threat to the survival of the San Joaquin kit fox is illegal shooting, while the long-range threat is the conversion of native habitat to agricultural use.

INTRODUCTION

On May 21, 1971 the California Fish and Game Commission declared the San Joaquin kit fox (*Vulpes macrotis mutica*) as rare pursuant to the California Endangered Species Act of 1970. Earlier action by the Commission in 1965 included declaring the kit fox a protected furbearer. Federal concern was expressed in 1966 when the Secretary of the Interior deemed it an endangered species.

In 1969 the California Department of Fish and Game became concerned about the hazards to the San Joaquin kit fox from rodent control campaigns in the San Joaquin Valley. The Pesticide Investigations Project and the U. S. Fish and Wildlife Service began a study of the San Joaquin kit fox to assess this hazard. The Special Wildlife Investigations Project participated when it became apparent there was no life history or food habits data available on the San Joaquin kit fox. The distribution and abundance of this species was reported on by Laughrin, 1970.

Thirteen adult and 15 pup San Joaquin kit foxes were trapped during the study. Twelve adults and 2 pups were fitted with biotelemetric equipment. This report presents the information gathered during the study, most of which was gained from the 14 radio tagged animals.

[1] This study was supported by Federal Aid to Fish and Wildlife Restoration Projects W-54-R "Special Wildlife Investigation," FW-1-R "Pesticide Investigations," and W-52-R "Wildlife Laboratory." Accepted for publication February 1972.

DESCRIPTION OF THE STUDY AREA

This study was conducted in Kern County. Most of the work was done on approximately 2 square miles of land in Buena Vista Valley, 10 miles northwest of Taft (Figure 1). Part of the area is within the boundaries of the Elk Hills Naval Petroleum Reserve, although most of the dens are just south of the reserve.

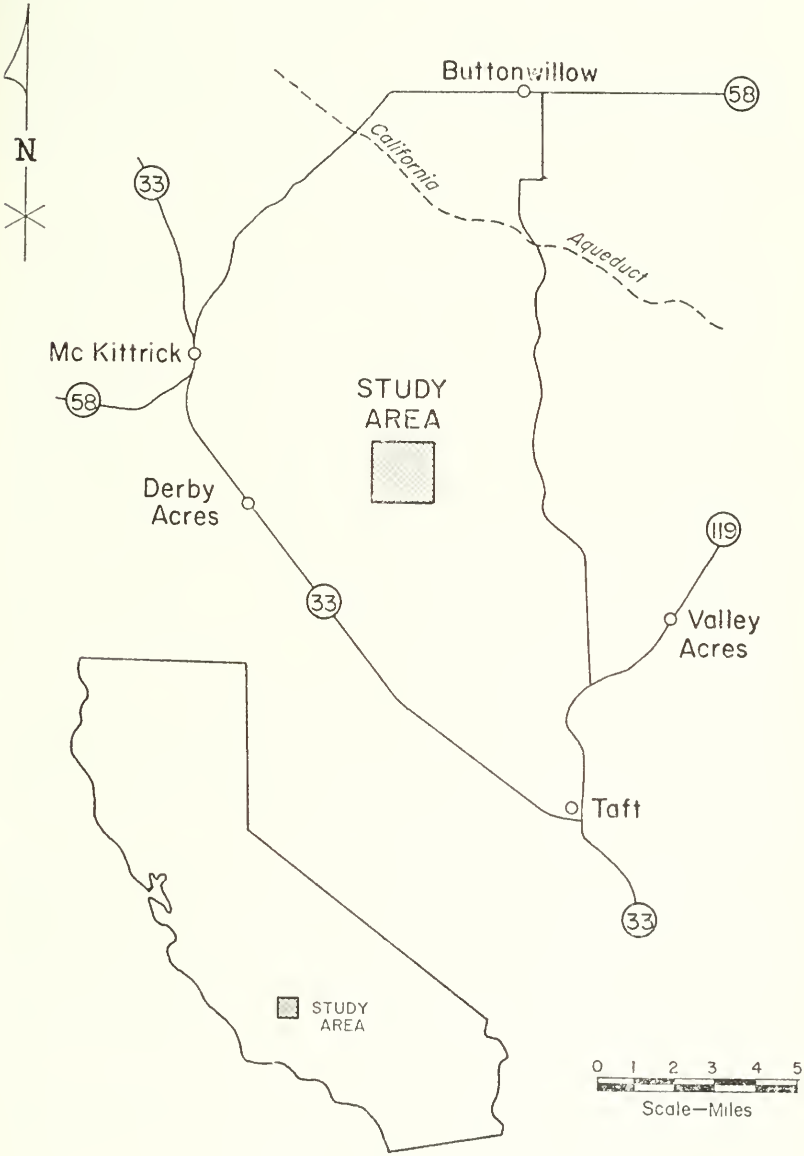

FIGURE 1. Location of San Joaquin kit fox study area

The native vegetation of this region (Munz, et al. 1965) is dominated by saltbush (*Atriplex polycarpa*). Bladderpod (*Isomeris arborea*) is abundant along washes and cheese bush (*Hymenoclea salsola*) is abundant in disturbed areas. Locoweed (*Astragalus lentiginosus*), thistle sage (*Salvia carduacea*), and bladder sage (*Salazaria mexicana*) are present. Small annuals bloom during the wet season. Filaree (*Erodium cicutarium*) is the dominant flower on the valley floor and also is abundant in the hills from February through April. Goldfields (*Baeria chrysostoma*), tarweed (*Madia radiata*), and gilia (*Linanthus liniflorus*) are common. The grasses *Bromus rubens*, *Festuca reflexa*, and *F. megalura* are abundant over the entire area, while *Schismus arabicus* is present but much less common. The grasses begin to grow with the first winter rains, and they die by May–July, depending upon the amount of moisture in the soil.

Representative animals in the area are listed in Appendix I.

The soil (Cole, et al. 1945) in Elk Hills is sandy clay, described as Kettleman loam, rough broken phase, while the soil on the valley floor is sandy described as Panochi sandy loam. Neither soil retains moisture. By July, the area is parched and brown, which it remains until the following winter.

The elevation on the floor of the valley is 1,000 ft. The adjacent hills rise to 1,200 ft and the nearby Elk Hills rise to over 1,500 ft. The valley plain, approximately 1.3 miles wide, is broken by numerous dry washes.

The climate of this region is that of a desert. Temperatures on the hottest summer days are 70 F at night and 115 F midday. Winter temperatures range from 30 F to 65 F. The average annual rainfall is approximately 6 inches, deposited almost entirely in winter and spring.

The major use of this land is for oil production, although sheepherders occasionally graze their flocks there in late winter or spring. Oil wells, storage tanks, pumping stations, and pipelines dot the landscape.

METHODS

A colony of foxes was studied intensively for 15 months to gather information on general activity and movements, food habits, reproduction and development, habitat requirements, and survival. Biotelemetry was used to locate and follow the daily movements of the foxes.

Capture of Study Animals

The study area was searched extensively on foot several times during the spring of 1970 for active fox dens. Kit foxes were trapped by setting live traps at active den sites. National live traps (32 x 12 x 16 inches) baited with sardines, kangaroo rats, or pieces of jackrabbit were used. Active dens were easily recognized during the spring by mounds of freshly excavated dirt, grass trampled by fox activity, and numerous scats and prey remains about den entrances. Dens were difficult to see at other times of the year.

Tagged foxes were retrapped at 3 month intervals by locating them by radio signal in their dens. Trapping at occupied dens was much more successful than trapping at random in the area.

Tagging

Trapped foxes were weighed; sexed; marked with numbered ear tags, females right ear, males left ear; checked for general physical condition; fitted with collars containing radio transmitters; and released. Pups received identical treatment, except they were not given collars until they were close to maturity in late June or July.

Telemetry Equipment

The radio transmitter was fastened to a collar of copper which was soldered in place around the fox's neck. The copper collar acted as the transmitting antenna. The collar, transmitter, and battery weighed 70–75 g. Within 24 hr the animals seemed unmindful of the collars.

After release, tagged foxes were located by use of a truck mounted Johnson Messenger 350/DF receiver and/or a Model D-11 portable receiver. A variety of directional and non-directional antennas was employed. In most cases it was possible to drive directly to occupied dens. If not, the portable receiver gave exact den locations.

As the distance between transmitter and receiver decreased, the signal volume increased. Each of the 12 transmitters broadcast on a different frequency, and we always knew which fox or foxes were being tracked. We could tell also which foxes were together when two or more different signals came from the same den.

The loop collar antenna around the neck of the animal was directional, with the strongest signal emitted in the plane of the antenna loop and the weakest in a plane perpendicular to the loop. It was thus possible to determine when an animal shifted position by the changing signal strength as the animal moved. With the signal at maximum strength, the range of reception was approximately $\frac{3}{4}$ to 1 mile.

OBSERVATIONS

Activity

The San Joaquin kit fox is basically nocturnal. Diurnal activity consists mainly of pups playing outside, but very close to the den on spring afternoons. The period for such play begins about 2 PM and lasts until 6 PM, although no single family is out of the den for longer than about 2 hr. Such activity may be observed every day until the families break-up in July or August.

Adult foxes are occasionally found outside the den in the afternoon at all times of the year, but most often in summer and fall. It is far more common, however, for adult foxes to remain in their dens all day, except when they have pups. They begin to emerge from dens shortly before sunset. The general pattern is to look out of the den to survey the surrounding area and then to come out completely if no danger is seen (Figure 2). The fox stretches, urinates, defecates, lies down on top of the den, finally leaves to hunt. Each fox emerges about the same time daily with respect to the sunset.

All hunting is at night. Sandy washes and areas around large bushes appear to be favored hunting sites, although foxes have been observed hunting throughout the area. Kit foxes hunt sporadically throughout the night. Foxes from different family groups will hunt in the same area, although not at the same time. This seems to indicate that no

FIGURE 2. San Joaquin kit fox at den entrance, fitted with radio transmitter collar

specific hunting territory is maintained or defended by any fox or group of foxes.

Each fox in this study apparently spent its life in an area of 1–2 square miles, with a great deal of overlap in home ranges.

Den Location

Unlike hunting areas, dens do belong to specific family groups. Each family of foxes has dens which are used only by the members of the family. Exceptions to this are rare.

Occupied dens were marked with a numbered stake and charted on a map. Three family groups were studied extensively, and their denning territories were apparent.

Large kit fox dens are frequently found in association with abandoned ground squirrel mounds. These dens may have been started by badgers digging after squirrels. Once a badger dug through the shallow hardpan, kit foxes could move in and continue the excavation in the loose soil beneath the hardpan. The hardpan layer is probably a formidable obstacle to foxes excavating new dens.

Den Use

Over the 15 month study period, tagged foxes were located in 71 different dens. Few of those dens could have been found without the use of telemetry.

Dens were abundant and most were vacant at any given time. Burrowing owls frequently established themselves in vacant dens.

The five members of a family group consisting of one fox (#30), his mate and two tagged of four pups in the litter from the first breeding season, and another mate from the second season, used at least 41 different dens between them in the 15-month study. Two of the 41 dens "belonged" to other fox groups.

From June through October, most of the adult foxes are solitary. The 3 months after the breeding season, they occupy dens smaller than the normal winter dens. Most of these dens have three entrances or less. In September and October, female foxes reoccupy the larger dens and clean and enlarge them. New entrances may be added at this time.

During October and November, the males join the females in the brood dens. Pairs are not always the same as the preceding year, although both members of a former pair may still be in the area. The large brood dens are occupied until May or June, when the foxes move to smaller dens. Unpaired foxes use small dens the entire year.

Kit foxes may use four or five different dens in a summer month. The animals move less in the fall and winter as they form pairs and breed. While the pups are being raised, den changes occur once or twice a month. Reasons for den changes are not known. A possibility is that a den change occurs when the available prey in an area is depleted.

Most dens are located in flat or gently sloping ground; hillside locations with slopes to about 30° are not uncommon, but dens on very steep slopes are rare. Fairly open areas with grass or with grass and scattered brush are used more for den sites than areas with thick brush. The number of entrances to the dens varied from one to ten, but dens with two entrances are most common. Large dens are quite complex affairs which are probably constructed continually over many years (Figure 3).

FOOD HABITS

Feeding

Paired kit foxes often hunt together in the same general area but not in any organized fashion. Adult foxes hunt for their pups until the pups are 3–4 months old. Up to this age, the pups spend their nights playing outside the den or sleeping inside.

I never saw adult foxes feed their pups anything other than kangaroo rats, although we were able to trap pups easily with either sardines or pieces of jackrabbit. Kangaroo rats are abundant in the spring. The adults bring the freshly killed kangaroo rats back to the den, where they are usually consumed by the pup above ground. The pups are fed one at a time, and there is little fighting among them over food. When one pup is fed, the adult fox is off to hunt again. Rarely does an adult fox require more than 5 min to catch a rat and bring it back to the den.

Numerous prey remains, mostly kangaroo rat and jackrabbit feet and tails and occasional bird feathers, are found scattered about den entrances where pups are present. Prey animals, especially kangaroo rats, are occasionally placed in ground squirrel or kangaroo rat holes near the den. Such prey items are often not recovered by the kit foxes.

Kit foxes eat road-killed animals of all kinds, and will take any meat offered them, even if old and decaying. Kit foxes apparently obtain adequate moisture from their prey, and do not need a source of drinking water.

Food Habits Analyses

Fresh scats and prey remains were collected around occupied kit fox dens on the study area and from similar habitat in Kern County; 23 scat groups from the study area and 29 from similar areas were ex-

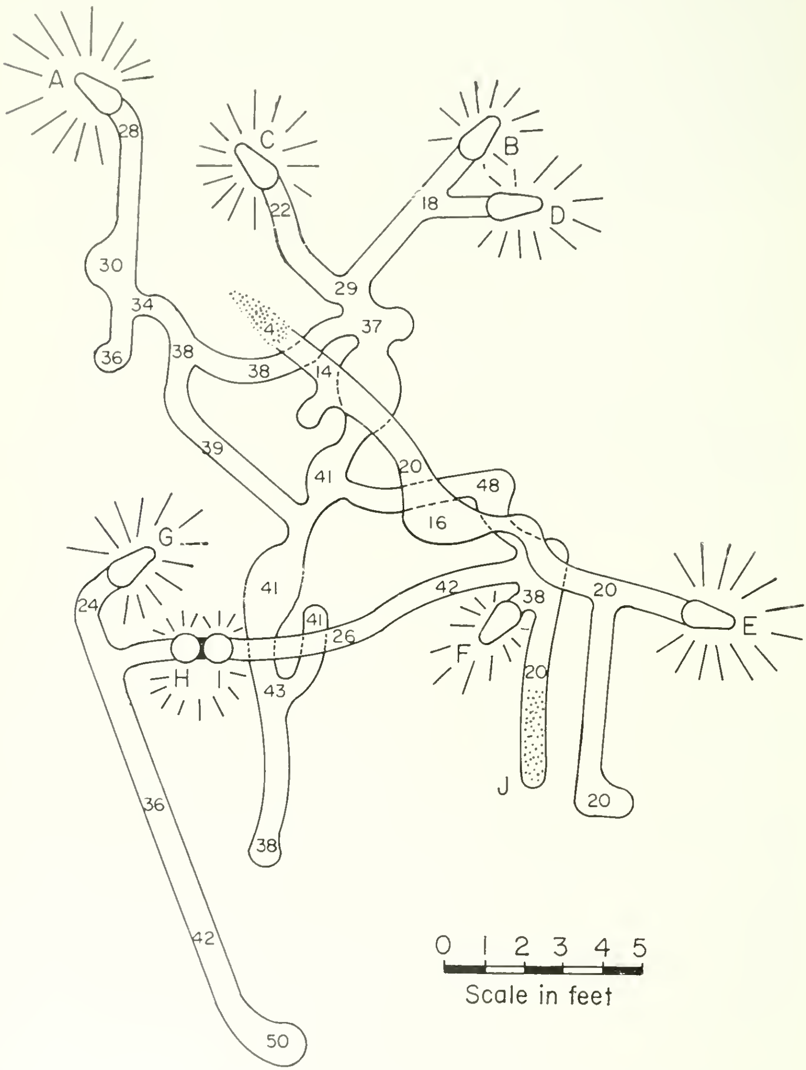

FIGURE 3. Structure of a large den. Numbers in tunnels are distances (in inches) from surface to bottom of tunnels; speckled areas are caved-in tunnels; letters denote den entrances. Measurements are as follows:

Entrance	Depth (inches) (measured from top of entrance to bottom of tunnel)	Width at surface (inches)	Diameter of tunnel at entrance (inches) (height x width)
A	16	36	9 x 6
B	13	27	8 x 6
C	13	30	8 x 6
D	10	23	8 x 5
E	10	12	11 x 4
F	18	12	9 x 6
G	12	22	9 x 5
H	15	Surface between entrance H and I was caved-in.	
I	15		
J	Entire entrance and tunnel were caved-in.		

Runways inside den were 5–6 inches high and 6–8 inches wide. Enlarged areas inside den were up to 10 inches high.

amined. The samples were obtained in the last half of each month to get an indication of seasonal fluctuations in the diet.

Results (Appendix II) indicate that kangaroo rats are the staple item of diet of the kit fox inhabiting the upper San Joaquin Valley. A glance at the coincidence of the distribution maps of this predator and prey will confirm that the kit fox is in the same ecosystem as the kangaroo rat. These rodents were found in the samples analyzed each month collected (July and September, 1969; March through November, 1970; and January through April, 1971). Rough volume percentage estimates, although not absolute in scat analysis, also indicate that kangaroo rats are the staple food item throughout the year.

The second most important food indicated by the analyses was rabbit, mostly cottontail. Although the data are sketchy because of small sample sizes and rough volume estimates, the results indicate rabbit is taken for food primarily during the spring and summer months. Scats collected in September, October, November, January and February, contained only traces of rabbit.

The kit fox, like most predators, is also an opportunist. A family of kit foxes denning adjacent to an alfalfa field near Buttonwillow in Kern County used gophers as the main part of their diet. Other food items found in the scats were pocket-mouse and ground squirrel.

Bird feathers and a few bone fragments were found in 9 of the 52 scat samples examined and lizard fragments in one. Adults and larvae of many kinds of insects including Jerusalem crickets, grasshoppers and ants, as well as scorpions and spiders, while not much by volume, occurred with a high frequency in the kit fox diet.

Vegetation did not contribute much to the diet, but stems, leafage, seed and pod fragments of soft chess, cheatgrass, red-stemmed filaree, peppergrass, wild plantain and a few unidentified forbs all occurred frequently in the scats. Grass and filaree seem to play a more than coincidental role in the kit fox diet.

Prey remains gathered at the entrances of dens along with the scat samples were identified as the hind feet of kangaroo rats, cottontail skin and fur, jackrabbit foot and leg bones, the upper jaw of a kit fox and feathers from a meadow lark.

GROWTH AND DEVELOPMENT

Physical Characteristics

Probably the two most distinctive physical characteristics of the San Joaquin kit fox are the very large ears and the black tipped tail. Adults have long legs in comparison to the rest of the body. The mean body dimensions for ten male kit foxes are: total length—805 mm, tail—295 mm, hind foot—124 mm, ear—87 mm; the mean body dimensions for nine female kit foxes are: total length—769 mm, tail—284 mm, hind foot—120 mm, ear—83 mm (Grinnell, 1937). The average adult male weight is 5.0 lb., while the female average is 4.6 lb. However, adult male weights have a wide range, and several males weighed less than females (Table 1). Pregnant females up to 6 lb. were weighed, but these weights were not included in the average. The heaviest fox, a male, weighed 6.5 lb.

Two distinct coats are developed each year: the summer coat is a tan color, the winter coat is a silver gray. The senses of smell and hearing are very well developed.

TABLE 1. **Kit Fox Weights (lb.) by Month**

	Jan.	Apr.	May	June	July	Aug.	Nov.	Dec.
Adult ♂ avg.	5.1(2)	5.5(3)	5.3(2)	------	------	5.0(3)	3.8(1)	5.2(4)
Range	4.5–5.7	5.1–5.9	5.0–5.7	------	------	4.1–6.2	------	4.5–6.5
Adult ♀ avg.	*5.6(3)	4.8(5)	4.4(2)	4.8(1)	4.8(3)	4.7(3)	4.9(3)	4.4(2)
Range	5.5–6.0	4.4–5.3	4.3–4.5	------	4.7–5.1	4.5–5.1	4.4–5.1	4.3–4.8
Pup ♂ avg.	4.6(1)	2.0(10)	2.9(4)	3.6(1)	4.6(3)	------	5.2(1)	4.2(1)
Range	------	1.9–2.4	2.6–3.3	------	4.4–4.8	------	------	------
Pup ♀ avg.	------	2.0(4)	3.0(1)	3.9(1)	3.5(2)	------	------	------
Range	------	1.8–2.2	------	------	3.0–4.1	------	------	------

* Pregnant.
( ) = sample size.

Rate of Growth

A kit fox pup develops the characteristic black tip on its tail at about 2 months of age. Puppy fur is replaced by the adult summer coat at 4–5 months. Those pups which were trapped repeatedly showed a weight gain of approximately ¾ to 1 lb. per month. Pups reach adult weight in July or August (about 5 months of age).

Parasites

Kit foxes occasionally support large populations of fleas, identified as sticktight fleas, *Echionorhoya gallinacea*. In addition to the fleas, ticks were occasionally found on the heads of study animals.

Voices and Calls

Both adult kit foxes and pups were observed to make three different sounds. These were classed as a burp, a growl, and a bark. The burp, a bubbling noise, closely resembled that made by a perking coffee pot. This sound was made by almost every adult kit fox trapped, while trapped pups made the noise only occasionally. The second noise, a growl, is a soft sound, frequently uttered when trapped foxes were approached. This sound may precede the bark, which is a highly pitched

and often rapidly repeated noise. The bark resembles that made by a small dog. I never heard a kit fox make any noises except when it was in a trap or being held, although Warden Robert Fischer reported that he has heard kit foxes make whistling noises as they hunt.

POPULATION DYNAMICS

Population Size

When the study began in April, 1970, six adult kit foxes and eight pups (two litters of four each) occupied an area of approximately 1 square mile. By August, at least four of the pups and one adult male had died or been killed. Only one of the eight pups stayed in the general area, and he moved out of the original square mile study area to the north. One of the five remaining adult foxes (male) also moved to the north of the original study area to breed with a different female in 1971. Two new male foxes moved into the square mile area to breed with the two solitary females. By April, 1971, the adult population in the study area was back to six. From this data, it appears that the population in the square mile area is stable at six adult kit foxes, with new animals recruited only as old animals leave.

Breeding and Care of Young

During the two breeding seasons covered by this study, 5 litters of pups were observed on the study area. One litter had five pups, three litters had four pups, and one litter had three pups.

Breeding begins in December and ends in January or February. Males may rarely fight over females during this period. Young are born in February or March. The pups do not emerge from the den until they are about 1 month old.

Both parents hunt food for the pups. The male may not stay in the same den with female and her pups, although he is usually in a den nearby.

The pups are cared for until they are about 4–5 months of age, when they begin to forage for themselves and the family group separates. A pup and one of its parents may occasionally be together in a den through the summer and fall. The pups sometimes stay together for a time after the family breaks up.

Previous research on kit foxes (Ingles 1958, Egoscue, 1956, 1962) indicates that they are monogamous. During this study the male kit foxes rarely had two mates in one season. Evidence indicates that the same male and female foxes do not mate year after year. Of the seven kit fox pairs observed in the two breeding seasons, only one pair had the same members both seasons. One male had at least three different mates in the two breeding seasons and was found with a fourth female one day. Kit foxes do not breed successfully their first year.

Mortality

Six kit foxes died in the 2 square mile study area. Three pups and one adult were apparently killed by varmint hunters, as evidenced by the removal from the carcass of ears and/or tails. One young adult (Fox #18) was shot, but her ears and tail were not removed. The decomposing remains of a tagged adult fox (Fox #1) were pushed out of a den along with his radio collar during den cleaning by a second fox. Cause of

death for this fox was not determined. From this evidence, it is apparent that the indiscriminate and illegal shooting of kit foxes is the most significant mortality factor affecting this population.

Starvation, especially in pups learning to hunt, is almost certainly a factor in limiting the size of the kit fox population. The total population may decline in years of low rodent populations.

The clearing of land of the native vegetation and conversion to agricultural use is an indirect mortality factor. Kit foxes occupying such areas are forced to emigrate to areas where the native habitat is intact. This usually results in overcrowding as the immigrant foxes compete with the resident kit foxes for space and food. Starvation of a portion of the fox population is the probable consequence.

Many kit foxes are killed by automobiles as the foxes feed on other animals previously killed on the highway. Road-killed foxes increase during periods when the kangaroo rat population is low, since more foxes are forced to scavenge along the roads in search of food.

ACKNOWLEDGMENTS

I am especially indebted to Dr. Mary Erickson, Robert Fischer, and Herbert Hagen for their advice and assistance during the course of this study, and to Howard Leach for his advice and aid through Special Wildlife Investigations. I also deeply appreciate the assistance of Gerald Edelbrock, Richard Fiant, Leslie Haworth, Riley Patterson, Frank Schitoskey, and Ronald Thomas. I thank Bruce Browning and Walt Stienecker for the food habits work, Oscar Brunetti for the parasite identification, and H. Jack Miller and the personnel of the Taft office of the California Division of Oil and Gas for their soil analysis. I appreciate the cooperation of Burt Snedden, in allowing me to work on his ranch property, and the personnel of the Elk Hills Naval Petroleum Reserve, especially Burch and Fred Caviness, in allowing me to work on the reserve property. Finally, I thank Stephen Herzog for his assistance with photographic processing.

Special Wildlife Investigations project provided funds for a seasonal aid. Project FWIR provided personnel to supervise the investigation and also provided the radio tracking equipment, radio tags and expertise in their use. FWIR personnel trapped and placed the radio tags on the foxes. U.S. Fish and Wildlife Service personnel also assisted in trapping and tagging.

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APPENDIX I. Animals in the Kit Fox Area

Mammals (Ingles 1967)
- San Joaquin kangaroo rat—*Dipodomys nitratoides*
- Giant kangaroo rat—*Dipodomys ingens*
- San Joaquin antelope ground squirrel—*Ammospermophilus nelsoni*
- Beechey ground squirrel—*Otospermophilus beecheyi*
- Deer mouse—*Peromyscus maniculatus*
- Southern grasshopper mouse—*Onychomys torridus*
- Black-tailed hare—*Lepus californicus*
- Audubon cottontail—*Sylvilagus audubonii*
- Badger—*Taxidea taxus*
- Coyote—*Canis latrans*
- Long-tailed weasel—*Mustela frenata*

Reptiles (Stebbins 1966)
- Desert horned lizard—*Phrynosoma platyrhinos*
- Leopard lizard—*Crotaphytus wislizenii*
- Side-blotched lizard—*Uta stansburiana*
- Western fence lizard—*Sceloporus occidentalis*
- Western whiptail—*Cnemidophorous tigris*
- Racer snake—*Coluber constrictor*
- Gopher snake—*Pituophis melanoleucus*
- Western rattlesnake—*Crotalus viridis*

Birds (migrants and residents) (Robbins, et al. 1966)
- Turkey vulture—*Cathartes aura*
- Marsh hawk—*Circus cyaneus*
- Red-tailed hawk—*Buteo jamaicensis*
- Golden eagle—*Aquila chrysaetos*
- Prairie falcon—*Falco mexicanus*
- California quail—*Lophortyx californicus*
- Mountain plover—*Eupoda montana*
- Killdeer—*Charadrius vociferus*
- Mourning dove—*Zenaidura macroura*
- Roadrunner—*Geococcyx californianus*
- Long-eared owl—*Asio otus*
- Short-eared owl—*Asio flammeus*
- Burrowing owl—*Speotyto cunicularia*
- Ash-throated flycatcher—*Myiachus cinerascens*
- Say's phoebe—*Sayornis saya*
- Horned lark—*Eremophila alpestris*
- Mockingbird—*Mimus polyglottos*
- LeConte's thrasher—*Toxostoma lecontei*
- Loggerhead shrike—*Lanius ludovicianus*
- House finch—*Carpodacus mexicanus*
- White-crowned sparrow—*Zonotrichia leucophrys*

APPENDIX II. **Food Items Found in Kit Fox Scat Analyses (Collected * in Kern County)**

	(23) Study area		(29) Other areas		(52) Totals	
	Frequency percentage	Frequency	Frequency percentage	Frequency	Frequency percentage	Frequency
Mammals						
Kangaroo-rats, *Dipodomys* sp.	91.3	21	72.4	21	80.7	42
Rabbits (Leporidae)	31.8	8	55.2	16	46.2	24
Squirrels (Sciuridae)	--	--	17.2	5	9.6	5
Cottontails, *Sylvilagus audubonii*	13.0	3	--	--	5.8	3
Pocket-mouse, *Perognathus* sp.	--	--	3.4	1	1.9	1
Invertebrates						
Unid. insect (Insecta)	73.9	17	48.3	14	59.6	31
Scorpions (Scorpionidae)	17.4	4	17.2	5	17.3	9
Jerusalem crickets, *Stenopelmatus longispina*	4.3	1	20.7	6	13.5	7
Insect larvae (Insecta)	8.7	2	13.0	4	11.5	6
Ants (Formicidae)	8.7	2	10.3	3	9.6	5
Grasshoppers (Locustidae)	8.7	2	3.4	1	5.8	3
Beetles (Coleoptera)	--	--	6.9	2	3.8	2
Spiders (Arachnida)	4.3	1	--	--	1.9	1
Vegetative						
Red-stem filaree seeds, awns, *Erodium cicutarium*	78.3	18	34.5	10	53.8	28
Grass seed, stem (Gramineae)	65.2	14	48.3	14	53.8	28
Cheatgrass seed, *Bromus tectorum*	39.1	9	31.0	9	31.6	18
Pepper-grass seed, pods, *Lepidium* sp.	21.7	5	17.2	5	19.2	10
Plantain seed, *Plantago* sp.	13.0	3	--	--	5.8	3
Forb leafage, stem	4.3	1	6.9	2	5.8	3
Vegetative fgmts.	--	--	10.3	3	5.8	3
Filaree seed, *Erodium* sp.	--	--	6.9	2	3.8	2
Soft chess seed, *Bromus mollis*	4.3	1	--	--	1.9	1
Wild buckwheat seed, *Eriogonum* sp.	4.3	1	--	--	1.9	1
Sunflower family seed (Compositae)	--	--	3.4	1	1.9	1
Wheat seed, *Triticum aestivum*	--	--	3.4	1	1.9	1
Rice seed, *Oryza sativa*	--	--	3.4	1	1.9	1
Watergrass seed, *Echinochloa crusgalli*	--	--	3.4	1	1.9	1
Fescue seed, *Festuca* sp.	--	--	3.4	1	1.9	1
Miscellaneous						
Bird feathers, claw	--	--	31.0	9	17.3	9
Unid. scales (lizard)	--	--	3.4	1	1.9	1
Unid. material	4.3	1	--	--	1.9	1

* July, September, 1969.
January–April, 1970.
January–April, 1971.

Calif. Fish and Game. 58(3): 175–178. 1972.

MELANISTIC MUTANT IN RINGNECK PHEASANTS[1]

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Melanistic pheasants exhibiting tremors have appeared in game farm ringneck pheasants. Matings over a 3-year period indicated that the abnormality was caused by an autosomal recessive gene. Abnormal chicks were produced by parents that received DDT in their diets.

INTRODUCTION

Abnormal offspring with increased pigmentation and muscular incoordination appeared in the progeny of ringneck pheasants (*Phasianus colchicus torquatus*) which received diets contaminated with DDT. Adult male plumage was typical in coloration and pattern but of a darker shade than normal. Plumage of adult females was dark brown barred with light brown in contrast to the brownish rust, brownish yellow and black of the normal ringneck (Figure 1).

The stock from which these melanistic pheasants originated has been maintained for over 15 years at a California Department of Fish and

[1] Supported by PHS grant ES 00161 from the Office of Resource Development, BSS (EH) and by PHS grant CC 00275 from the Communicable Disease Center, Atlanta, Georgia. Accepted for publication March 1972.

FIGURE 1. Adult female ringneck pheasants—normal (left), melanistic (right).

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Game game farm. Over 750,000 pheasant chicks were produced during this period but no instance of melanism was reported. Buff and light buff plumage color mutants from this stock have been described by Asmundson, Abbott and Lantz (1964). The melanistic mutant propagated by pheasant fanciers and described by Bruckner (1939), like the buff mutant, had three genotypic combinations of a pair of alleles represented by three phenotypes.

The primary purpose of our studies was to assess the effects of DDT on pheasant reproduction.

METHODS

Exposures to DDT were varied in pattern, duration and concentration. Several groups of test birds were fed diets containing different levels of DDT. Insecticide levels in the feed were 0, 10, 100 and 500 parts-per-million (ppm) DDT in 1964 trials; 0, 10, 100 and 250 ppm in 1965; and 0, 10, and 100 ppm in the 1966–67 trials. Investigative techniques and preliminary results (1964) have been published (Azevedo, Hunt and Woods, 1965).

Parents of the first generation pheasants were fed 500 ppm DDT diets continuously for about 3 weeks prior to egg laying, then once a week during the breeding season. As adults the first, second and part of the third generation ringneck pheasants received 100 ppm DDT diets exclusively before and during the egg laying period. Most of the third generation ringneck adults received feed with 10 ppm DDT before and during egg laying; none of the melanistic birds were fed diets with DDT.

RESULTS AND DISCUSSION

Three tremulous, melanistic chicks hatched in 1965 (Table 1) from first generation ringneck parents died within 3 weeks. In 1966, 11 (3 ♂ and 8 ♀) melanistic chicks were produced by second generation ringneck pheasants. Six of the 11 lived to adulthood. Twenty-three (12 ♂ and 11 ♀) melanistic chicks were produced by third generation ringnecks fed 10 ppm DDT diets and three (1 ♂ and 2 ♀) by third generation ringnecks on 100 ppm diets. Ten of the 26 melanistic chicks hatched in 1967 lived for two or more months.

TABLE 1. Occurrence of Melanistic Chicks Among the Progeny of Pheasants Fed DDT Contaminated Diets

Year	Generation	Cross ♂	Cross ♀	Mating period in days	DDT in diet (ppm)	Ringneck ♂	Ringneck ♀	Total*	Melanistic ♂	Melanistic ♀	Total
1964	Parental	1	10	35	500	--	--	171	--	--	0
1964	Parental	1	10	35	500	--	--	182	--	--	0
1965	First	1	9	28	100	--	--	124	1	--	3
1966	Second	1	14	28	100	46	43	89	3	8	11
1967	Third	1	9	21	100	20	18	38	1	2	3
1967	Third†	1‡	13	35	10	38	55	83	4	4	8
1967	Third	1‡	9	42	10	41	43	84	8	7	15

* Totals are for all chicks that hatched or pipped, including chicks that were not sexed.
† Larger 10 ppm group.
‡ The same male was mated with the two groups of females.

Both sexes continued to tremor as adults except when relaxed—i.e., when roosting or when placed on their backs. Melanistic adults lacked

sufficient coordination for normal flight and walked with a faltering gait. Two adult melanistic pheasants (1 ♂ and 1 ♀) hatched in 1966 died from mechanical causes prior to the 1967 breeding season. The surviving male and three females were placed in a breeding pen.

Although the melanistic male developed plumage and other characteristics usually associated with male pheasants in the breeding season, there was no evidence that he either attempted to mate or successfully mated with the melanistic females. The three females produced 127 infertile eggs while with the melanistic male. Egg laying started about 9 days after that of the third generation normal ringneck adults. For the melanistic females the eggs per hen were 44.3 and for normal ringneck hens of the same parentage 38.5. The rate of lay for melanistic females was 0.599 egg per hen day and 0.486 for third generation normal ringneck hens. The male and one female died near the end of the egg laying period. A third generation ringneck male that produced melanistic progeny (1967) was placed with the melanistic females, and subsequently six infertile eggs were produced. Artificial insemination of the melanistic females was not attempted.

Because of their dark color and squatting walk the melanistic chicks appeared smaller but were actually of the same size and weight as their normal siblings. Among day old melanistic chicks, females averaged 17.3 g and males 18.2 g. The melanistic chicks were alert, responded quickly to visual and audio stimuli and were aggressive. During brooding they tended to associate more with each other than with normal ringneck chicks.

The design of the feeding trials precluded individual pedigree matings, consequently we could not determine exactly the expected number of melanistic or normal chicks. The approximate number of melanistic chicks that could be expected was computed by assuming that one female and the male in the first generation (1965 trials) were carriers of an autosomal recessive gene for melanism. If the assumption was correct, about 51% of the second generation (1966) and 57% of the third generation (1967) ringneck females were heterozygous to melanism. The approximate number of melanistic chicks that could be expected was 3.5 in 1965, 12.5 in 1966, 5.7 for the 100 ppm dietary group in 1967, and 12.3 and 13.7 for the two 10 ppm dietary groups in 1967. Forty melanistic chicks were produced during the 3 years. We could not determine the number of normal chicks produced by pheasants potentially heterozygous for melanism; therefore, the chi-square test was applied only to the melanistic chick data. The chi-square value was 3.054 ($P > .20$) when the 1965 and 1966 data were pooled as was that from the 100 ppm and the larger 10 ppm dietary group in 1967. There was no significant difference between the number of melanistic chicks observed (Table 1) and the approximate number expected.

This melanistic mutant was probably an autosomal recessive as indicated by the phenotype and sex ratios. The occurrence of the mutation among pheasants which received high dietary levels of technical DDT may have been coincidental. Whether or not the melanistic birds were sterile remains to be adequately tested. The pigment defect and the neuromuscular symptoms may indicate that the cells of the neural crest in the early embryo were affected by the mutation. There are examples

(Cloudman and Bunker, 1945) in vertebrates where pigment anomalies and neural muscular deficiencies have been associated. The significance of DDT in the origin of the mutation was not established.

ACKNOWLEDGMENTS

We thank Ursula K. Abbott, Department of Avian Science, University of California, Davis Campus for assistance in preparation of the manuscript.

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Calif. Fish and Game, 58(3): 179–190. 1972.

DIEL CHANGES IN THE VERTICAL DISTRIBUTION OF THE EUPHAUSIIDS, *THYSANOESSA SPINIFERA* HOLMES AND *EUPHAUSIA PACIFICA* HANSEN, IN COASTAL WATERS OF WASHINGTON[1]

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Time-depth related variations in Isaacs-Kidd trawl catches of the euphausiid, *Thysanoessa spinifera*, in continental shelf waters of Washington during the summer of 1967 suggest that this species performs diel vertical movements. During the hours of 0800 to 1500 moderate size catches of *T. spinifera* were obtained from deep water (35 to 53 fathoms), but mid-depth (20–27 fathoms) and near surface tows (7–10 fathoms) during this period yielded negligible numbers of euphausiids. After 1500 hours catch rates from deep water increased markedly, but by evening the availability of *T. spinifera* had shifted from deep water to mid- and near-surface depths. High catch rates were sustained from near-surface waters throughout the late evening and early morning hours (2200 to 0500 hours). A similar pattern of availability with time and depth was found for the euphausiid, *Euphausia pacifica*.

INTRODUCTION

Information on the diel changes in the vertical distribution of *Thysanoessa spinifera* and *Euphausia pacifica* was obtained in conjunction with investigations on the diel changes in the vertical distribution and schooling integrity of Pacific hake, *Merluccius productus*, in the late summer of 1967. The interest in *T. spinifera* was prompted by the discovery that this euphausiid contributes substantially to the diet of Pacific hake at least during the spring-fall periods in Washington waters (Alton and Nelson 1970). The diel and geographical changes in the availability of Pacific hake to harvesting methods may be in some way related to behavioral and distributional features of its chief prey, *T. spinifera*. *E. pacifica* was included because it was also encountered in large enough numbers to show a pattern of availability with time and depth, providing further information on diel changes in the vertical distribution of this wide ranging and important North Pacific euphausiid.

Thysanoessa spinifera (Figure 1) is essentially a neritic species which occurs in some abundance in the coastal waters of the Gulf of Alaska south to California (Brinton, 1962; Nemoto, 1966; Day, 1971). It also occurs in the Bering Sea (Nemoto, 1962).

E. pacifica (Figure 2) is distributed throughout the boreal waters of the North Pacific and also occurs in the Bering and Okhotsk seas. It is the most numerous of the euphausiids in the coastal waters of California (Brinton, 1962), Oregon (Hebard, 1966), and Washington (Day,

[1] Accepted for publication November 1971.

1971). A small and seasonal fishery for *E. pacifica* is conducted in Japanese waters (Komaki, 1967).

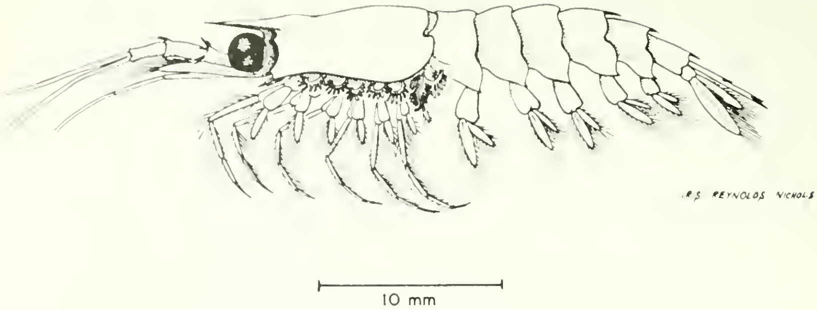

FIGURE 1. The euphausiid, *Thysanoessa spinifera.*

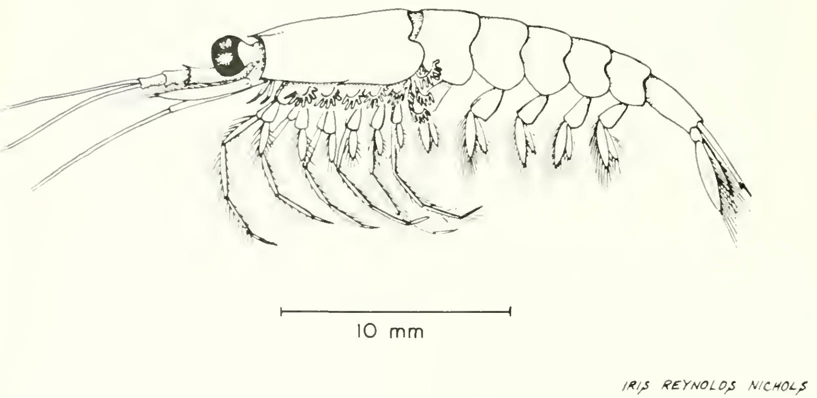

FIGURE 2. The euphausiid, *Euphausia pacifica.*

METHODS

Equipment and Sampling Procedures

Sampling was conducted from the National Marine Fisheries Service vessel, *John N. Cobb,* during two 10- to 11-hr sampling periods and one 18-hr period. The 10- to 11-hr periods encompassed the evening and early morning hours (approximately 1800 hours to 0530 hours). The 18-hr period was from 0400 to 2200 hours.

During each period horizontal tows were made with a 6-ft Isaacs-Kidd trawl at about 6 to 10 fathoms below the sea surface, at mid-depths of 20 to 27 fathoms, and at 6 to 10 fathoms above the sea bottom usually every 3 hr. Bottom depth varied from 42 to 53 fathoms. All tows for a given period were begun at approximately the same LORAN position and made in the same general direction.

The body and intermediate sections of the trawl were constructed of 3½-inch mesh webbing and lined completely with ¼-inch mesh nylon webbing. The codend was also of ¼-inch mesh nylon webbing. All webbing was dark green in color.

Trawl depth was determined by an electrical depth telemetry system developed for positioning large fish trawls (Lusz, 1967). The telemetry system consists of a depth sensing unit located at the termination of a $\frac{5}{8}$-inch diameter electromechanical trawl cable and a depth-readout device in the pilothouse.

Sampling procedure remained essentially the same for each tow. The trawl was set as the vessel moved slowly ahead. When a predetermined amount of cable was let out, the telemetry system was activated, and the trawl either raised or lowered to the sampling depth by varying the speed of the vessel. When the trawl was at sampling depth the vessel's speed was adjusted until the trawl stabilized. This usually required less than a minute and demonstrated the stabilizing capabilities of the Isaacs-Kidd trawl. The duration of the tow at sampling depth was 15 min. When the horizontal tow was completed, the vessel was speeded up until the trawl was about 5 fathoms above the sampling depth thus minimizing sinking of the trawl below sampling depth during retrieval. The time required to lower the net to sampling depth varied from 2 min for sampling depths of 7 to 10 fathoms, to 7 min for sampling depths of 44 to 45 fathoms. It generally took about 1 min longer to retrieve the net than it had to set it. Hence setting and retrieval time for near surface tows was one quarter of the total sampling time but for the deepest tows it was one-half of the total sampling time.

A LORAN position was taken at the beginning and end of each tow. From the LORAN positions the distance covered by the vessel while towing at the sampling depth was determined. Using the calculated distance and the length of time required to cover this distance, the average speed of the vessel and trawl was approximated. Vessel speed ranged from 3.2 to 6.0 knots.

Echogram records were collected during each tow. The entire catch from each tow was placed in a plastic bag containing a 10% solution of buffered formalin. After removal of the catch, the trawl was carefully rinsed with a stream of sea water.

Enumeration of Trawl Catches

The procedures used to enumerate the euphausiid catches were as follows:

1) The bulk of non-euphausiids (mainly jellyfish, ctenophores, and fish) were separated from the catch.
2) If the catch was large, a subsample was obtained by means of a Folsom plankton splitter (McEwen, Johnson, and Folsom, 1954). For small catches (1,500 to 3,000 individuals) the subsample represented from 37 to 50% of the total catch. For extremely large catches (24,000 to 34,000 individuals) the subsample represented 5 to 7% of the total. In the case of the largest catch, estimated at 44,000 individuals, two subsamples of between 2,000 and 3,000 individuals each were obtained.
3) Both the subsample and the remainder of the catch were drained and placed on absorbent paper for 10 min, and then weighed to the nearest gram. After weighing, volumes were determined by water displacement. Volumes were measured to the nearest 5 ml.
4) The euphausiids in the subsample were separated by species and within species the adults were separated from the subadults.

Adults ranged in size from 15 to 28 mm for *Euphausia pacifica* and from 15 to 32 mm for *Thysanoessa spinifera*. Individuals less than 15 mm in length were considered subadults. Euphausiids were measured from the tip of the rostrum to the end of the telson. The adults and subadults of each species were enumerated.

5. The number of adults and subadults of each euphausiid species in the subsample was multiplied by the ratio (total weight of catch)/(weight of the subsample) to obtain an estimate of the total number of individuals in the above categories. These results were checked by making a second estimate based on volume ratios. Estimates presented in this report are from the weight-number relationship.

Catch Per Unit Effort

Ideally there should have been some means of determining the volume of water filtered by the trawl, so that the catches would represent a quantitative measure, for example, the number per cubic meter, of the euphausiids present in the water sampled. Also it would have been desirable to have had the trawl mouth open only during the 15-min period at the depth of sampling. Since these features were not incorporated into the sampling, the catch is expressed in relation to the time that the trawl was in the water and to the speed of the trawl, so that sampling effort between tows could be roughly equated. Thus rather than present a measure of the density of euphausiids, our results are expressed in terms of catch per unit of sampling effort.

The catch of individuals was divided by the total time in minutes that the trawl was in the water. This figure of catch per minute was then adjusted for the speed of the trawl. We assumed that throughout the entire period the trawl was in the water, it was traveling at a speed calculable from the distance traveled by the vessel during the tow. All catch rates (number per minute) were adjusted to the lowest trawling speed recorded (3.2 knots), so that the catch rate from a tow at 3.2 knots would remain the same but one from a tow that traveled twice that speed would be halved. We are assuming that the only difference in sampling between a tow at one speed and one at another speed is the volume of water filtered per unit time, disregarding possible factors such as the increase in the avoidance capability of euphausiids with decrease in towing speed or changes in filtering efficiencies at different speeds.

RESULTS

Euphausiids were encountered in large numbers at three of the four locations sampled (Figure 3). Some of the largest catches (24,000 to 44,000 individuals) occurred during the evening and early morning hours (1800–0530 hours) of July 19–20 and August 2–3. Other sizable catches (5,000 to 13,600 individuals) were obtained during the period of 0400 to 2130 hours on July 24. On July 28 sampling began at 1830 hours but was terminated at 2330 hours because only small catches (4 to 70 individuals) were taken; the data from this period are not included here.

Thysanoessa spinifera and *Euphausia pacifica* were the only species of euphausiids encountered.

Changes in the Availability of Euphausiid Species by Time and Depth

Thysanoessa spinifera

There was a marked difference between daytime and nighttime availability of adult *T. spinifera* (Figure 4). During daylight hours of 0800 to 1500 hours the catch rates of adults were low from all sampled depths but increased sharply in the late afternoon first from near-bottom depths and then later in the evening from near-surface depths. Throughout the late evening and early morning hours large catches continued to be made near the surface.

The shift in abundance from near-bottom depths to near-surface depths by time was especially noticeable during the evening of July 19 (Table 1). Early in the evening (1800–2000 hours) the highest catch rate (645 adults/minute) was obtained from near-bottom depths

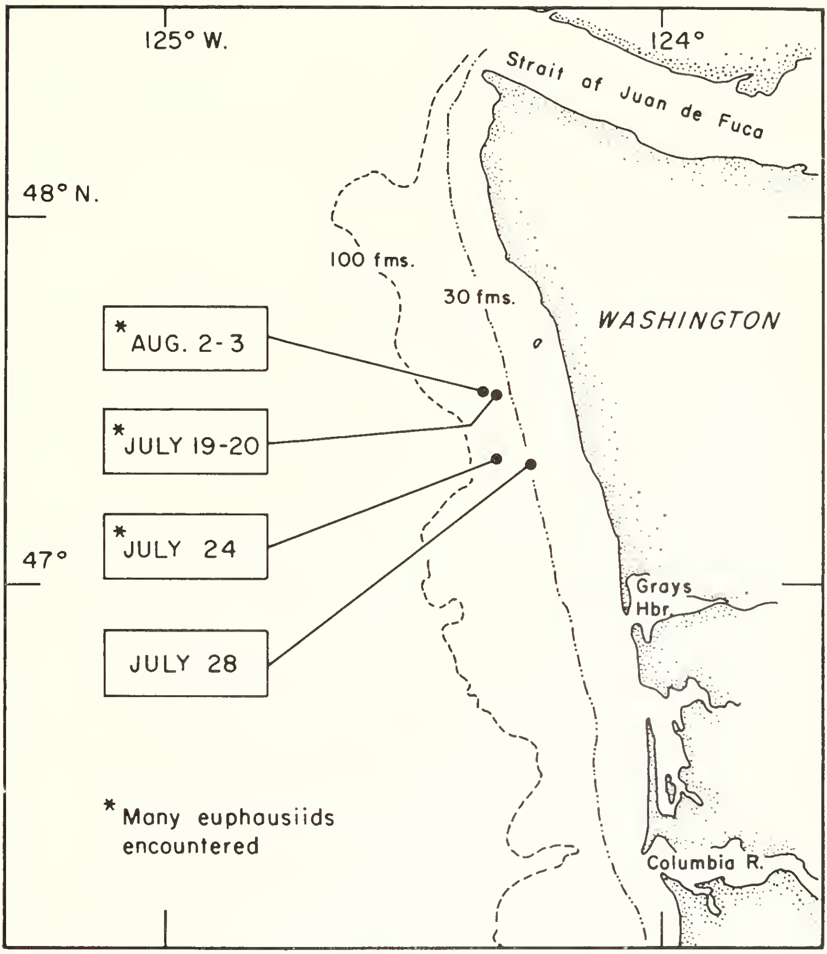

FIGURE 3. Localities off the coast of Washington where trawling for euphausiids took place in 1967.

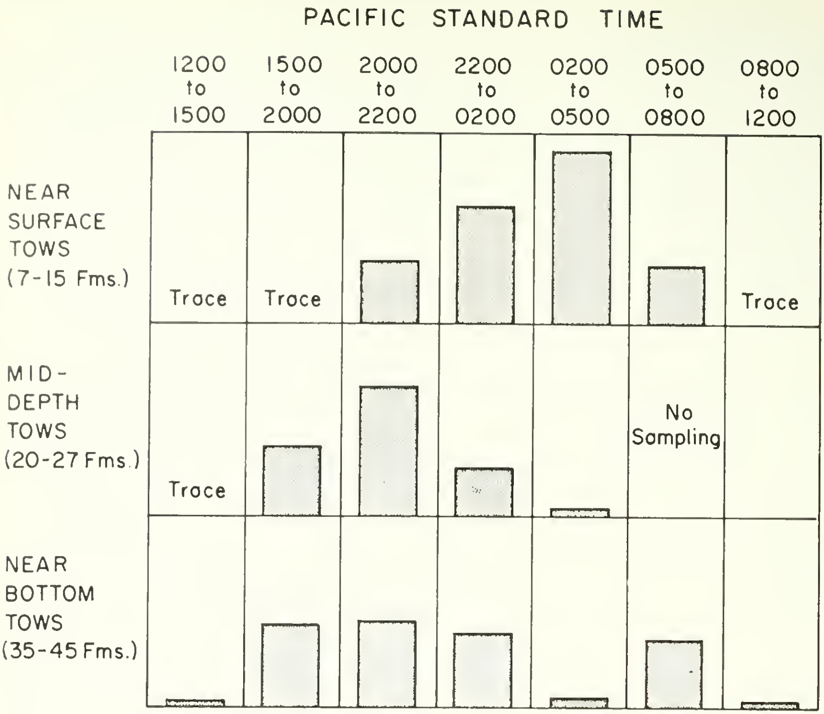

FIGURE 4. Availability pattern of adult *Thysanoessa spinifera* by time and depth in Washington coastal waters during July and August of 1967. Bottom depths varied from 42 to 53 fathoms. The height of the columns are proportional to the catch rates. Sunrise was between 0430 hours and 0500 and sunset was between 1950 and 2110 hours.

TABLE 1. **Isaacs-Kidd Trawl Catches of the Euphausiid, *Thysanoessa spinifera*, During the Period from 1800 Hours on July 19 to 0530 hours on July 20. Catches Are Given as the Number of Adults and Juveniles (in parentheses) per Minute of Trawling Adjusted for Differences in the Speed of the Trawl Between Tows (see text). Locality: Off the Coast of Washington (lat 47°43′ N, long 124°41′ W) Over Bottom Depths of 42 and 46 Fathoms**

Time	Depths sampled (fathoms)		
(PST)	7-10	20	35
1800 2000	0.7(3.4)	103.1(2.6)	644.7(2.6)
2100 2200	No sampling	508.8(4.2)	185.8(3.3)
2200 2300	583.9(1.5)	No sampling	No sampling
0000 0200	484.7(3.8)	236.2(2.6)	266.1(1.6)
0300-0500	525.0(2.1) 468.9(2.4)	No sampling	38.0(0.3)
0500 0600	305.5(1.0)	No sampling	No sampling

and the lowest catch rate (less than one adult/minute) was obtained from near-surface depths. Between the hours of 2100 and 2300 the reverse occurred with the largest catch rates being encountered from near-surface depths and the lowest from near-bottom depths, although the catch rates from mid- and near-surface depths were almost equal. The catch rates from near-surface depths remained high for the remainder of the sampling period. Some sizeable catches from mid- and near-bottom depths were made after midnight, but part of these catches were probably obtained near the surface while setting and hauling the net.

Results from the August 2–3 sampling (Table 2) did not show a shift in availability of *T. spinifera* with time and decreasing depth in the evening hours but did indicate a greater nighttime availability of *T. spinifera* from near-surface waters than from other depths. The highest catch rates from near-surface waters occurred after midnight.

TABLE 2. Isaacs-Kidd Trawl Catches of the Euphausiid, *Thysanoessa spinifera*, During the Period from 1900 Hours on August 2 to 0500 Hours on August 3. Catches Are Given as the Number of Adults and Juveniles (in parentheses) per Minute of Trawling Adjusted for Differences in the Speed of the Trawl Between Tows (see text). Locality: Off the Coast of Washington (lat 47°32′ N, long 124°43′ W) Over Bottom Depths of 43 and 44 Fathoms

Time	Depths sampled (fathoms)		
(PST)	7–9	24–25	36
1900–2000	No sampling	68.1(12.0)	9.4(0.7)
2000–2200	94.3(4.8)	No sampling	113.2(0.9)
2200–0000	70.4(3.0)* 81.0(0.8)	56.8(2.4)	No sampling
0000–0200	890.1(0)	86.8(4.1)	No sampling
0200–0500	308.9(0)	20.9(0.4)	10.7(0.5)

* Tow was at 15 fathoms.

Sampling on July 24 provided information on the availability of *T. spinifera* during daylight hours. From 0500 to 1500 hours catches of adults from near-surface and mid-depths were negligible (Table 3). Catches from near the sea bottom varied, being high at 0600 and 1530 hours but rather low (11 adults/minute) at 0900 and 1300 hours. There was a shift in the availability of the adults from near-bottom depths to near-surface depths during the period of 1500 to 2200 hours.

Catches of subadults were quite small during all sampling periods (Tables 1 to 3) and this was due to some degree to the large mesh openings of the web which allowed small individuals to pass through.

Euphausia pacifica

E. pacifica was obtained in large numbers during only one of the four sampling periods, the evening of July 19 and early morning of July 20 (Table 4). The availability of adult specimens by time and depth during this period (Figure 5) was similar to that of *T. spinifera*. Early in the evening a large catch of *E. pacifica* was taken from near the sea bottom, but catches from mid- and near-surface were negligible.

Later, at about 2100 to 2300 hours, the largest catches were from mid- and near-surface waters. Though the remainder of the evening and in the early morning hours till 0400, the highest catch rates were from 7- to 10-fathom range.

Subadults of *E. pacifica* were numerous only during the July 19–20 period, and in most instances were much less abundant than the adults in samples (Table 4). Frequently when the adult catch was high, the subadult catch was high also. The highest catch of subadults (1,049 specimens) were obtained from near the sea surface at 2230 hours.

TABLE 3. **Isaacs-Kidd Trawl Catches of the Euphausiid, *Thysanoessa spinifera*, During the Period from 0400 Hours to 2130 Hours on July 24. Catches Are Given as the Number of Adults and Juveniles (in parentheses) per Minute of Trawling Adjusted for Differences in the Speed of the Trawl Between Tows (see text). Locality: Off the Coast of Washington (lat 47°23′ N, long 124°40′ W) Over Bottom Depths of 50 to 53 Fathoms**

Time	Depths sampled (fathoms)		
(PST)	7–8	25–27	44–45
0400–0500	72.3(4.4)	2.2(1.6)	No sampling
0500–0800	0.4(0.2)	0 (T)	174.2(3.9)
0800–1200	0.2(0.8)	T(1.6)	11.6(1.5)
1200–1500	0.4(0.3)	0(2.2)	11.3(2.3)
1500–1700	No sampling	No sampling	162.5(1.5)
1700–2000	T(T)	367.9(3.9)	32.8(4.6)
2000–2200	230.0(3.1)	159.8(5.0)	41.9(2.6)

T = trace, only 1–4 specimens in total catch.

TABLE 4. **Isaacs-Kidd Trawl Catches of the Euphausiid, *Euphausia pacifica*, During the Period from 1800 Hours on July 19 to 0600 Hours on July 20. Catches Are Given as the Number of Adults and Juveniles (in parentheses) per Minute of Trawling Adjusted for Differences in the Speed of the Trawl Between Tows (see text). Locality: Off the Coast of Washington (lat 47°31′ N, long 124°41′ W) Over Bottom Depths of 42 and 46 Fathoms**

Time	Depths sampled (fathoms)		
(PST)	7–10	20	35
1800–2000	0(0.1)	0.2(0)	210.6(12.6)
2100–2200	No sampling	65.4(13.2)	28.5(8.6)
2200–2300	219.9(35.0)	No sampling	No sampling
0000–0200	196.6(16.9)	76.9(5.2)	49.4(14.8)
0200–0400	167.2(6.6) 200.7(6.4)	No sampling	No sampling
0400–0600	0.8(2.3)	No sampling	40.3(3.8)

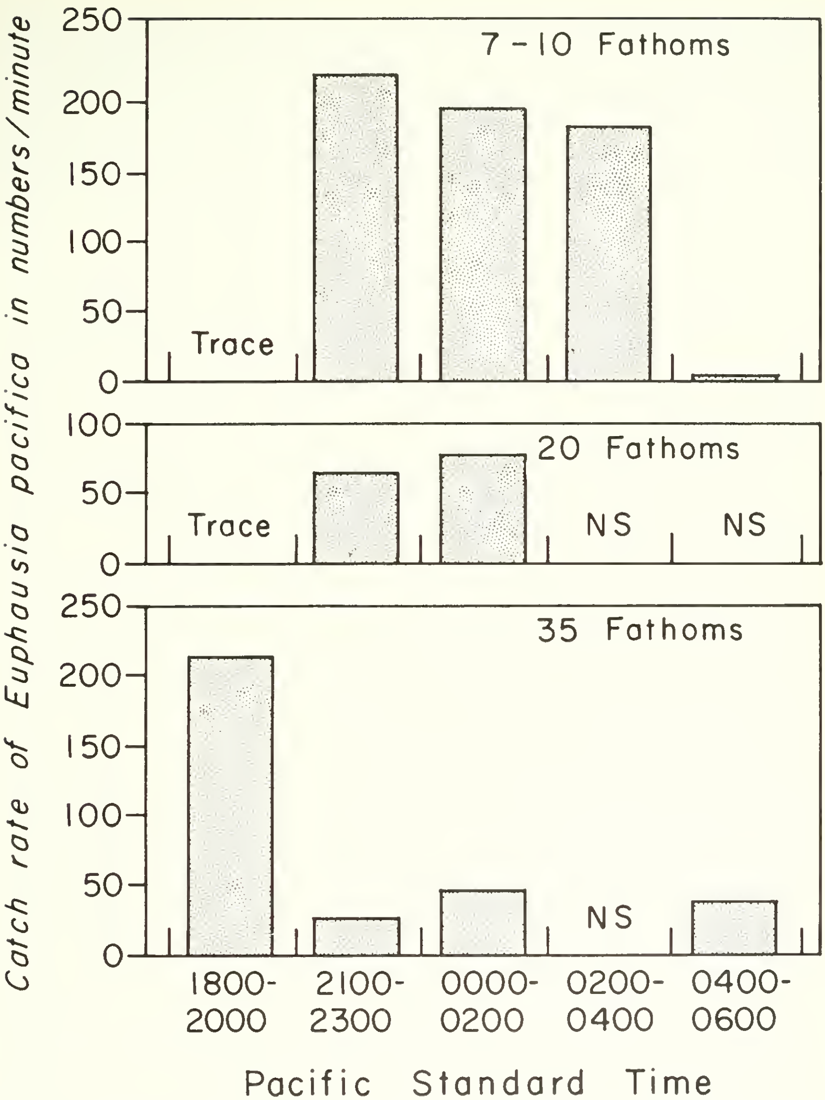

FIGURE 5. Availability of adult *Euphausia pacifica* by time and depth during the period of 1800 hours on July 19 to 0600 hours on July 20. Sampling took place off the coast of Washington over bottom depths of 42 to 46 fathoms. NS = no sampling; trace = less than 0.5 euphausiid captured per minute of trawling.

Temperatures and Sound Scattering in Areas of Euphausiid Sampling

Surface temperatures during the time of sampling varied from 13 to 15 C. A pronounced thermocline (about 6 C temperature change in 5 fathoms of depth) was present at a depth of about 5 to 10 fathoms (Figure 6). Nearly isothermal conditions prevailed from about 20

fathoms depth to the sea bottom. Associated with the thermocline were one and often two sound-scattering layers that were consistently present at depths of approximately 7 to 15 fathoms in all sampling locales. Pronounced changes in the appearance of the layers occurred during twilight hours and were believed to be related to changes in the vertical distribution of animals at that time. To illustrate these changes in the sound-scattering layers, echograms obtained during the August 2–3

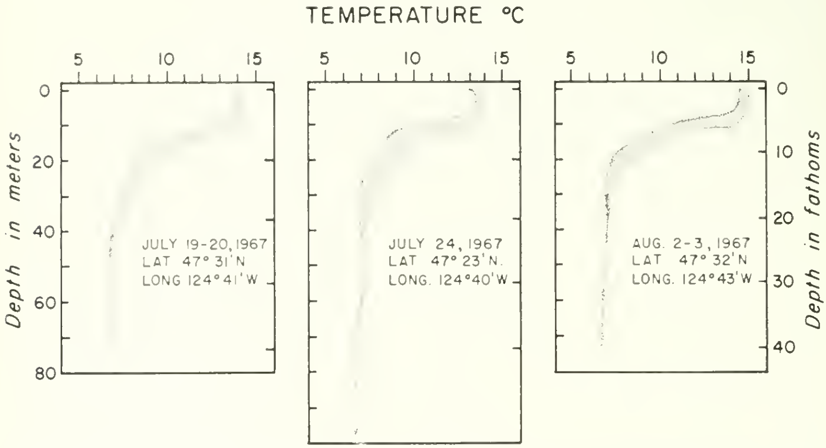

FIGURE 6. Depth-temperature profiles during Isaacs-Kidd trawling in Washington coastal waters.

sampling are presented in Figure 7. The vertical extent of the layers were much greater early in the evening (1945 hours) and in the morning (0410 hours) than at any other time. Of significance is the wavy appearance of the layers in the early evening hours which suggests that depth adjustments may be being made by the animals comprising these layers in response to changing light conditions. It was not possible to associate any of the sound scatterings specifically to euphausiids.

DISCUSSION

The availability pattern of *Thysanoessa spinifera* by time and depth suggests that this species undertakes a diel vertical movement, at least during the time and localities where sampling took place. This upward movement from near-bottom depths begins late in the afternoon. By late evening (about 2200 to 2400 hours) the euphausiids have reached near-surface depths and remain there throughout the early morning hours. It is difficult to determine from the catch data when the descent from near-surface waters begins, but after 0600 hours very few individuals were encountered from near-surface and mid-depths. Since *T. spinifera* was not available in any sizeable numbers from near-bottom to near-surface depths during the daylight hours of 0800 to 1500 hours, it is assumed that the main population may be below the depths sampled during this period. *Euphausia pacifica* has a timing similar to *T. spinifera* in its diel vertical movements. Since light is a governing factor in the vertical movements of euphausiids (Lewis, 1954) varia-

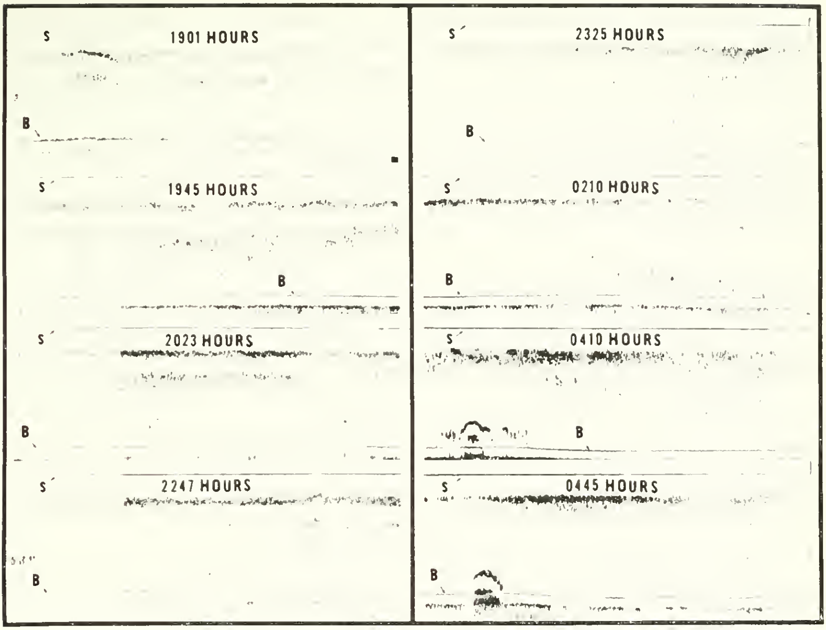

FIGURE 7. Echograms (38.5 kHz sounder) obtained during Isaacs-Kidd trawling in Washington coastal waters (lat 47°32′ N; long 124°43′ W) on the evening of August 2 and the morning of August 3, 1967. Bottom depths were 42 to 43 fathoms. S = sea surface; B = sea bottom.

tions in this depth-time movement of *T. spinifera* and *E. pacifica* can be expected as a result of changing light intensities due to cloud conditions and season.

Several investigators (Esterly, 1914; Boden, 1950; Brinton, 1962 and 1967) have reported on the diel vertical migration of *E. pacifica*. However, there has been little available data prior to this study suggesting a similar movement in *T. spinifera*. In fact Brinton (1962) in his study of North Pacific euphausiids found no evidence that *T. spinifera* has a diel vertical movement. During zooplankton surveys off the coast of Washington, Day (1971) found adult *T. spinifera* above 150 m of depth at twilight and darkness, but never above this depth during daylight hours. He questioned his findings because of the possibility that *T. spinifera* may have been able to avoid his net, a 3-ft Isaacs-Kidd trawl, during daylight hours.

Other investigators have found evidence of net avoidance by euphausiids. Jerde (1967) observed that a plankton net with a 2.3 m^2 mouth opening caught more adult euphausiids per unit volume of water filtered than a plankton net with a 0.785 m^2 mouth opening, indicating that the euphausiids were able to avoid the smaller net to a greater degree than the larger one. Similarly, Marr (1962) noted that daylight surface tows made with a 70-cm diameter plankton net obtained no adult *Euphausia superba*, but that there was some degree of capturing success using the larger 100-cm diameter net. A study by Mauchline (referred to by Mauchline and Fisher, 1969) indicated that large in-

dividuals of the euphausiid, *Meganyctiphanes norvegica*, escaped capture by nets (100-cm diameter mouth opening) being towed at speeds less than 1 m per second (2 knots).

The above findings suggest there is an optimum mouth opening size and towing speed, determined by the euphausiid's visual acuity, reaction time, and swimming speed, which would make net avoidance negligible.

Because of the rather large mouth opening of the Isaacs-Kidd trawl and the relatively high speeds (3.2 to 6.0 knots) at which it was towed, we have assumed that net avoidance by *T. spinifera* was not important. The great disparity between day and night catches from the upper water column is interpreted as a scarcity of *T. spinifera* during the daytime and an abundance during the hours of darkness. The near absence of *T. spinifera* from midwater and near-surface waters in hauls made during daylight hours and the progressive increase in abundance first in mid-depth hauls, then in near-surface hauls, during late evening and early morning indicate that the *T. spinifera* population engaged in a diel vertical movement during the study period.

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Calif. Fish and Game, 58(3): 191–197. 1972.

POPULATION DIFFERENCES IN THE SWELL SHARK *CEPHALOSCYLLIUM VENTRIOSUM*[1]

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Emigration of swell sharks between Santa Catalina Island and the nearby California mainland is prevented or severely restricted by the intervening deep basin. Reproductive isolation is shown by an extreme difference in egg-case tendril length between the two populations. Supporting evidence is found in differences in egg-case size and relative fin size. Two egg-cases from Isla Guadalupe, Mexico, have the same tendrilless configuration as those from Santa Catalina Island, suggesting that this is an insular character.

INTRODUCTION

The swell shark, *Cephaloscyllium ventriosum* Garman (= *C. uter*), family Scyliorhinidae, is common in the waters of California from Monterey Bay south. It is occasionally found as far south as Acapulco, Mexico, and is found in Chilean waters (Kato, Springer and Wagner, 1967). In these regions, it also inhabits the waters of at least some of the adjacent islands.

Around Santa Catalina Island, California, trapping and direct observations using SCUBA diving gear indicate that the sharks are normally found in depths of 20–40 m both day and night; they are found less abundantly at other depths. Swell sharks are distinctly nocturnal (Nelson and Johnson, 1970). They are found during the day in the crevices of rocky reefs, and enter traps more readily at night. Two specimens have been taken in deep trap sets off Santa Catalina Island; one from about 160 m (pers. comm., F. Brocato), and one from about 360 m (pers. comm., S. Applegate).

In the course of a general investigation of the reproductive biology of this shark I found gross morphological differences between the egg-cases of sharks from Santa Catalina Island and those of sharks from the nearby mainland. This led me to look for and find other differences between the sharks from these locations.

MATERIALS AND METHODS

Sources of Study Material

Sharks were captured by cage trap and while SCUBA diving at various locations off the mainland coast in the vicinity of Los Angeles and at Santa Catalina Island, California. All egg-cases from which measurements were taken were live eggs, less than 2 weeks old, laid by these captured sharks in the Marineland of the Pacific laboratory tanks. In addition, both live and empty egg-cases obtained while diving

[1] Contribution No. 32, Marineland of the Pacific Biological Laboratory. Accepted for publication February 1972.

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as well as preserved egg-cases in the Scripps Institution of Oceanography Museum were examined.

The samples of sharks measured for morphometric comparison came from the mainland side of Santa Catalina Island, in or near Isthmus Cove, and from the region of Point Dume, approximately 10 km north of Los Angeles on the mainland (Figure 1). Both samples were meas-

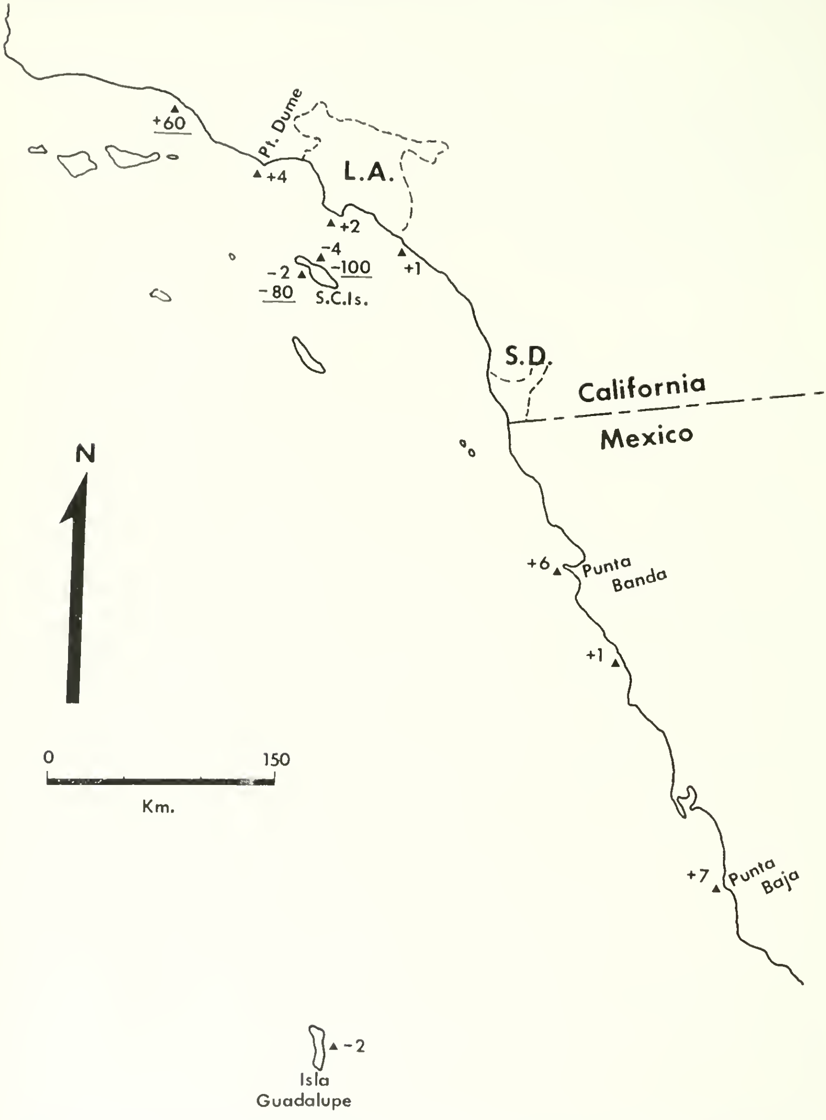

FIGURE 1. Source locations of egg-cases. The triangles mark the locations. Underlined numbers are approximate numbers of egg-cases laid in the laboratory by sharks from that location; non-underlined numbers are the egg-cases found in nature at that location. The + and − signs indicate the presence or absence of tendrils on that sample of egg-cases. L.A. = Los Angeles; S.D. = San Diego; S.C. Is. = Santa Catalina Island.

ured on the same day. Both had been fresh-frozen for storage, and were measured after thawing. In addition, preserved specimens in the Scripps Museum collection, from Isla Guadalupe, Santa Catalina Island, and various points on the mainland were compared for color, pattern, and gross morphological differences. Measurements from some of these specimens were taken also but are not used for comparison with the fresh specimens described above, because of the dimensional changes in the cartilaginous skeleton of elasmobranchs caused by formalin and alcohol preservation (pers. comm., S. Springer).

Measurements of Egg-cases

Egg-cases were dried with a paper towel, then weighed on a triple-beam balance to the nearest 0.1 g. Duplicate weighings showed the mean error to be less than ± 0.1 g. Widths were measured at the widest point of the egg-case to the nearest millimeter; the mean error of duplicate measurements was less than 1 mm. The length of the egg-case was the total length excluding the tendrils. Because this involved an arbitrary decision as to just where the tendrils started, I would estimate the error in this measurement to be on the order of 1–2 mm. I did not use the least length between horns (Cox, 1963) because of the wide variations found in the morphology of both ends of these egg-cases.

Measurement of Sharks

The dimensions ultimately chosen for population comparisons were total length, height of the first dorsal fin, and width of the caudal fin (Table 2). Because of the very flexible body of the swell shark, such dimensions as jaw width, body depth, gill slit width and interspace, etc., were not reproducible with any accuracy. The dorsal fin height measurements were consistently reproducible if the fin was spread flat on the table surface; one point of the caliper was placed in the notch at the posterior fin base and the other point swung in an arc at the fin tip. The caudal fin widths were taken in a similar manner; the caliper was swung in an arc from a point on the edge of the lower caudal lobe at the widest point of the tail, to the dorsal edge of the tail.

RESULTS

Edwards (1920), Daniel (1934 and earlier editions), and Cox (1963) have all figured single egg-cases of the swell shark. Edwards' figure clearly showed long tendrils at the four corners of the egg-case. Those of Daniel and Cox showed egg-cases with tendrils broken off, but both authors described the tendrils as long and coiled on newly-laid eggs.

My first sample of swell shark egg-cases was laid by sharks captured near the California mainland. All had tendrils from 80 to over 200 cm in length. The next sample came from sharks captured on the inshore side of Santa Catalina Island; the egg-cases had no tendrils over 2 cm long. The tendrils were not broken off; they had the same filamentous ends as the long tendrils on egg-cases from mainland sharks. Aiyar and Nalini (1938) have described a similar difference between the egg-cases of *Chiloscyllium griseum* found at Madras, India, and those found at Malabar.

The function of an anchor has often been ascribed to tendrils on elasmobranch egg-cases, and tendril-bearing eggs are indeed often found

entangled in marine algae strands and detritus. The mainland coast of California receives frequent moderate to heavy surf. The inshore side of Santa Catalina Island, sample source for the tendril-less eggs, rarely undergoes surf action. To check this correlation between surf action and the presence of long tendrils on egg-cases, I obtained a sample of sharks from the offshore side of Santa Catalina Island, which has surf like that of the mainland. The eggs of these sharks, like those from the sheltered inshore side of the island, had no tendrils over 2 cm (with the exception of one pair which had 15 cm tendrils at one end). Further samples, from field and laboratory, confirmed this pattern. Figure 1 shows sample source areas, sizes of egg-case samples and indicates whether the samples were laid in the laboratory or field, as well as the known distribution of egg-cases with and without tendrils. Note that only the Santa Catalina Island and Isla Guadalupe samples lack tendrils.

The discovery of this consistent difference in the tendril morphology of egg-cases laid by sharks from different locales prompted a search for other egg-case differences. The lengths, widths, and weights of two samples of eggs were measured; one sample was laid one year by sharks captured at the mainland near Los Angeles, the other was laid the next year by sharks captured at Santa Catalina Island. The results of two-tailed t-test comparisons of these measurements show that the probability of the samples being from the same population is less than 0.01 for length and weight, and less than 0.05 for width (Table 1).

TABLE 1. Comparisons by Two-tailed t-test of Measurements of Egg Samples from Sharks Captured at Isthmus Cove, Santa Catalina Island and the Mainland Near Los Angeles.*

	Source	n	$\bar{x}$	var.	p
Length (in mm)	M C	20 28	114.700 121.186	78.013 25.769	<0.01
Width (in mm)	M C	20 28	41.850 44.714	19.819 4.138	<0.05
Weight (in gm)	M C	20 28	26.593 32.546	34.503 11.865	<0.01
Weight†	M C	14 26	29.593 32.996	11.874 9.581	<0.01

* C = Santa Catalina Is.; M = mainland; p = probability that the samples are from the same population. The calculations were done by computer. The results were rounded to three decimal places for this table.
† This comparison between weights was done between only those eggs containing an ovum, because of the difference in weight of eggs without an ovum, and the difference in the proportion of such eggs in the two samples.

Visual comparison of preserved shark specimens from various mainland locations, Santa Catalina Island, and Isla Guadalupe showed considerable variation in color and pattern of markings, but no consistent differences. There were no readily apparent differences in the gross morphology of the sharks from these different areas or in the fresh samples used for morphometric comparison. However, statistical comparison showed that both the first dorsal fin and the caudal fin were relatively larger in the Santa Catalina Island sample than in the sample from near Point Dume on the mainland. The ratios obtained by

dividing the total length by, respectively, the height of the first dorsal fin (T.L./H.D.I), and the width of the caudal fin (T.L./C.W.), for the two samples were compared by two-tailed t-test. Both samples had sex ratios which were strongly biased, but in opposite directions (Table 2). Because of this bias, the difference in fin proportions between both entire samples could be attributed either to a population difference or to sexual dimorphism, which is found in some parameters in some scyliorhinids (Brough, 1937). However, the differences in those parameters tested are significant between populations, and not between sexes within the same population (Table 3).

TABLE 2. Body Measurements (in mm) Used for Morphometric Comparisons

Part A. Sharks captured in or near Isthmus Cove, Santa Catalina Island

Sex	T.L.	H.D.I	C.W.
Female	796	55	69
Female	805	60	74
Male	906	68	82
Male	875	67	80
Male	771	55	70
Male	837	--	78
Male	700	59	61
Male	869	64	81
Male	895	65	79
Male	662	49	62
Male	750	52	65
Male	794	55	71
Male	787	51	74

T.L. = total length; H.D.I = height of the first dorsal fin; C.W. = width of the caudal fin; F = fin frayed, not measurable.

PART B. Sharks Captured Near Point Dume, California

Sex	T.L.	H.D.I	C.W.
Female	824	5y0	71
Female	831	52	71
Female	820	52	70
Female	802	53	69
Female	738	F	62
Female	809	51	71
Female	764	53	67
Female	812	53	72
Female	731	48	63
Female	759	51	68
Female	845	50	70
Male	803	55	68
Male	718	F	62
Male	659	F	57
Male	792	F	66
Male	734	--	62

Ratios to total length were calculated for other parameters such as the height of the second dorsal, caudal width at the notch and insertions of the fins; no significant differences between populations or sexes were apparent.

Precaudal vertebral counts were obtained from whole body x-ray films of small samples of sharks from Isla Guadalupe, Santa Catalina

TABLE 3. **Comparisons by Two-tailed t-test of Morphometric Ratios of Different Samples of Sharks (see Table 2) from Isthmus Cove, Santa Catalina Island, and Point Dume, California***

Source	Sex	n	$\bar{x}$ T.L./H.D.1	$\bar{x}$ T.L./C.W.	var.	p
D	both	11	15.509		0.613	<0.01
C	both	12	13.767		0.781	
D	both	16		11.638	0.061	<0.01
C	both	13		11.031	0.116	
D	F	10	15.600		0.580	<0.05
C	F	2	13.950		0.605	
D	M	5		11.760	0.027	<0.01
C	M	11		11.000	0.114	
D	M	5		11.760	0.027	1.00
C	F	11		11.580	0.070	
C	M	11		11.000	0.114	1.00
C	F	2		11.200	0.180	
C	M	10	13.730		0.878	1.00
C	F	2	13.950		0.605	

* C = Santa Catalina Is.; D = Pt. Dume; T.L. = total length; C.W. = width of the caudal fin; H.D.1 = height of the first dorsal fin; p = probability that samples are from the same population. The calculations were done by computer. The results were rounded to three decimal places for this table.

Island and various points on the mainland. The results were inconclusive but suggested that Isla Guadalupe swell sharks might have a slightly lower count.

DISCUSSION

Three types of differences have been found between samples of the populations of swell sharks found at Santa Catalina Island and at the nearby mainland; the presence or absence of long egg-case tendrils, absolute egg size, and relative fin size. The difference in egg-case tendril morphology is the most obvious and supported by the most data. This difference in egg-case morphology is as valid as any other consistent difference between the individuals of two populations. It is consistent, whether the eggs are found in nature or laid in laboratory aquaria. This suggests genetic rather than environmental control. The absence of exceptions to or intergrades between the two tendril types in the two locations studied (with the exception of the one instance mentioned) further suggests reproductive isolation. The small sample of tendril-less egg-cases from Isla Quadalupe suggests that the lack of tendrils may be a more widely distributed insular character.

Santa Catalina Island is only 30 km from the mainland but the intervening basin is nearly 1,000 m deep. This is a reef-dwelling shark, apparently not given to swimming in mid-water. Thus, it seems most likely that this basin is an effective geographical barrier which prevents, or at least severely restricts, migration between these populations.

It is doubtful, but conceivable, that there was a treatment difference in the laboratory—i.e., feeding, handling, temperature—between the two samples of sharks which produced the eggs which I compared (Table 1), and that such difference caused difference in egg-case sizes between the two samples. The morphometric data on relative fin size, despite their statistical significance, would be more satisfactory if the

sample sizes were larger, and without a sex ratio bias. While these data on egg-case and fin size differences cannot stand alone as proof of population separation, they are supportive when considered with the data on tendril morphology.

It has been suggested that the Santa Catalina Island and mainland populations should be described as separate species on the basis of this difference alone (pers. comm., C. Hubbs). This has not been done, however, because of the lack of knowledge of the distribution of the difference (no data from any other island except Guadalupe), and the uncertain state of the relationships within the genus as a whole along its eastern Pacific distribution, (pers. comm., S. Springer).

ACKNOWLEDGMENTS

This work is dedicated to the memory of the late Charles H. Turner, formerly of the Terminal Island Laboratory, California Department of Fish and Game. His sudden death was a great loss to his friends and fellow biologists.

I wish to thank Dr. R. Fay of Pacific Bio-Marine Supply, Mr. J. Prescott and the collectors of Marineland of the Pacific, and the Santa Catalina Island Marine Biological Laboratory for assistance in obtaining animals. Dr. S. Applegate, Los Angeles County Museum, Mr. S. Springer, U.S. Bureau of Commercial Fisheries, Drs. C. Hubbs, R. Rosenblatt, and Mr. L. Taylor, Scripps Institution of Oceanography, have all contributed assistance or valuable discussion of the work in progress. My thanks also to Dr. W. S. Hoar, University of British Columbia, who provided support during the later phases of the work.

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Calif. Fish and Game, 58(3): 198–203. 1972.

DDT RESIDUES IN WHITE CROAKERS[1]

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The level of DDT residues in white croaker (*Genyonemus lineatus*) flesh (group A) and flesh with the skin left on (group B) was determined by gas liquid chromatography. The percent fat in group A and group B also was determined. There are significant differences ($P < .01$) between levels of DDT and between the percent fat in the two groups. The fat determined for group A was 3.76% (SE=0.37%) and for group B was 6.06% (SE=0.48%). The total DDT residue (including pp′DDT, its metabolites and isomers) for group A was 10.82 ppm (SE=0.96 ppm) and for group B was 18.23 ppm (SE=1.95 ppm). The only residues detected at the limit of detection of 0.01 ppm were 1,1-dichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl)ethylene, (op′DDE); 1,1,1-trichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl)ethane, (op′DDT); 1,1-dichloro-2,2-bis(p-chlorophenyl) ethane, (pp′DDD); and 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, (pp′DDT). Many of the samples analyzed exceeded U. S. Food and Drug Administration guideline tolerance of 5.0 ppm wet weight for total DDT.

INTRODUCTION

The California Department of Fish and Game is monitoring the chlorinated hydrocarbon pesticide residues present in various species of marine fish from the California coast. Selected results are exchanged with the California Department of Public Health and the United States Food and Drug Administration. The California Department of Public Health is interested in pesticide residues which may have an adverse effect on the health of Californians. A tolerance of 5 ppm DDT (including all metabolites and isomers of pp′DDT) in fish offered for sale on the market has been established by the U. S. Food and Drug Administration. When pesticide residues are over the established tolerances, the appropriate agency takes necessary action.

In the fall of 1970 we found residues of DDT lower than those found by the Food and Drug Laboratory in Los Angeles in similar samples of white croakers. The Food and Drug Laboratory analyzed the white croaker whole less the head and viscera. Department of Fish and Game Pesticide Laboratory personnel analyzed the fish as skinned fillets only. Based on the lower results obtained and the presence of an appreciable amount of oil in the skin of fish (Love, 1970), a preliminary study was performed to determine if the skin contributed significantly to the total pesticide residue in the sample. Encouraging results in the preliminary study led to the final study upon which this paper is based.

The fish in this study were white croakers from the Los Angeles-Long Beach Harbor area collected in the fall of 1971. They were taken from California Department of Fish and Game Block 719, in the immediate vicinity of the Long Beach Lighthouse.

[1] This study was supported by Federal Aid to Fish and Wildlife Project FW-1-R "Pesticides Investigations." Accepted for publication March 1972.

Fish and Game data indicate that marine fish from the coastal waters of southern California are more contaminated with chlorinated hydrocarbons than most freshwater fish in the state and most marine fish from the northern California coastal area. This has been traced, in part, to high releases of DDT into the Los Angeles sewer system by the Montrose Chemical Company DDT plant (Parkhurst, 1971, and Schmidt, et al. 1971). This excessive release of DDT has since been curtailed by Montrose. Since DDT is a long-lived pesticide it will remain in circulation in the area for a period of many years (Risebrough et al. 1970).

METHODS AND MATERIALS

Sixty-eight white croakers were measured and divided into 14 groups according to length-frequency modes (Table 1). The fish were split longitudinally along the backbone after the heads and tails were cut off. One half of each fish was filleted as flesh only and the skin was left on the other half. Composite samples of flesh only are referred to as group A and those with flesh and skin as group B. Each sample of flesh or flesh plus skin was finely chopped in an Osterizer. Equal amounts of the chopped flesh or flesh plus skin from each fish in each length-frequency group were composited by grinding in a Hobart Food Chopper. Fourteen composite samples in both group A and group B were prepared. Three identical subsamples from each composite were weighed. One set of subsamples was analyzed by Department of Fish and Game Pesticide personnel, one set was analyzed by Food and Drug personnel in Los Angeles and the third set was kept frozen in reserve.

TABLE 1. Average Length and Percent Fat for White Croaker Flesh (A) and Flesh Plus Skin (B)

Number of fish	Average length (cm)	Sample	Percentage fat	Sample	Percentage fat
6	20.2	1A	3.72	1B	8.80
6	21.0	2A	6.17	2B	4.50
6	21.8	3A	3.51	3B	5.71
6	22.3	4A	1.80	4B	3.44
5	23.0	5A	2.65	5B	5.80
5	23.2	6A	4.56	6B	5.84
5	24.1	7A	1.03	7B	3.88
5	24.0	8A	2.81	8B	5.29
5	25.0	9A	5.19	9B	8.47
5	25.0	10A	3.22	10B	5.22
5	25.5	11A	4.48	11B	6.33
3	26.0	12A	4.99	12B	9.34
3	27.0	13A	3.75	13B	4.94
3	28.3	14A	4.76	14B	7.28
		Average	3.76		6.06
		SE	0.37		0.48

Approximately 40 g of each composite sample were thoroughly blended with four times its weight of anhydrous granular sodium sulfate (J. T. Baker reagent grade) in an Osterizer food blender. The samples were extracted by percolating 500 ml of warm n-Hexane (Mallinckrodt Nanograde) through a filter funnel filled with Whatman No. 40 ashless filter paper. The resulting extract was concentrated to 100 ml by blowing a stream of clean, dry air over the samples on a steam

bath. Fifty ml of each sample concentrate were passed through a 4-inch column of Florisil 100/120 mesh (Floridin Company, Tallahassee, Florida) topped with 1 inch of anhydrous granular sodium sulfate. The inside diameter of the column was ⅞ inch. The pesticides were eluted from the column with 250 ml of 15% diethyl ether in hexane. The eluate was concentrated to 100 ml as previously described and then analyzed by electron capture gas chromatography.

The gas chromatographic instrument was a Varian-Aerograph Model 2100 equipped with tritium electron capture detectors. Injector and detector temperatures were 201 C; column temperature was 180 C. The carrier gas was high purity nitrogen run through a molecular sieve trap at a flow rate of 80 ml per min. The columns used were 6 ft long by ⅛ inch I.D. pyrex glass. For routine determinations a tandem 50-50 mixed column of 3% QF-1 and 3% DC-200 on 80/100 mesh Gas Chrom Q was used. The op'DDE quantification and identification was done with a tandem 90-10 mixed column of 3% DEGS and 3% DC-200 on 80/100 mesh Gas Chrom Q. In both columns the DC-200 was packed on the detector end of the column for reduction of column bleed problems.

The percent fat in each sample was determined by blowing a stream of air over 50 ml of the original hexane extract solution in a 100 ml beaker which was heated gently on a hotplate. After the volume was reduced to a few ml the solution was transferred quantitatively to a weighed planchet. Again, this was gently heated and a stream of air blown across the surface. When the solution had thickened considerably and the odor of hexane could no longer be detected, the planchets were taken off the hotplate and set aside to cool. After 2–3 hr, the planchets were placed in a desiccator overnight and then weighed the next day.

RESULTS AND DISCUSSION

Each sample in groups A and B was analyzed for percent fat content (Table 1). The values for group A and group B were significantly different ($P < .01$) as determined by paired t-test analysis (Winer, 1962). The average value of the percent fat of group A was 3.76 (SE = 0.37%). The average value of group B was 6.06 (SE = 0.48%).

Each sample in groups A and B was analyzed for pesticide residue content (Tables 2 and 3). The paired t-test analysis showed the residues in groups A and B to be significantly different for all metabolites and isomers of pp'DDT detected ($P < .01$). Group A DDT residues were 38% lower than those in Group B. Group A fat levels were 37% lower than those for group B.

The values for total DDT, 10.82 ppm (SE = 0.96 ppm) for group A and 18.23 ppm (SE = 1.95 ppm) for group B are significantly different ($P < .01$). The relationship of DDT residues in flesh plus skin versus flesh is described by the curve $y = 1.8054x - 1.2990$ ($r^2 = 0.7944$, $F = 46.371$, $df = 13$, $P < .01$), Figure 1.

The levels of DDT found in this study were verified by chemists of the U. S. Food and Drug Laboratory in Los Angeles. They also found a significant difference ($P < .05$) between DDT residues in groups A and B.

The difference in results between the Fish and Game laboratory and the Food and Drug laboratory originally noticed in the group of white croakers analyzed during the fall of 1970 has been resolved. The differ-

ence is explained by the selection of a different type of sample from the fish for analysis. When pesticide residue results are to be used interchangeably from different laboratories it is critical that the type of samples analyzed be the same. This is especially true when tolerance values of regulatory agencies are being considered.

TABLE 2. Residues of DDT Metabolites and Isomers in White Croaker Flesh (ppm)

Sample	op'DDE	pp'DDE	op'DDT	pp'DDD	pp'DDT	Total DDT
1A	0.94	10.93	0.34	2.36	0.49	15.06
2A	1.71	13.69	0.35	3.00	0.81	18.56
3A	0.75	7.82	0.19	1.19	0.33	10.28
4A	0.80	9.28	0.18	1.12	0.42	11.80
5A	0.92	10.31	0.26	1.43	0.55	13.47
6A	0.66	6.78	0.29	1.54	0.48	9.75
7A	0.31	6.00	0.17	0.69	0.29	7.46
8A	0.33	4.56	0.24	0.91	0.26	6.30
9A	1.23	9.66	0.32	1.93	0.67	13.81
10A	0.41	4.55	0.16	1.01	0.23	6.36
11A	0.90	9.08	0.32	1.81	0.52	12.63
12A	0.54	6.67	0.22	1.39	0.37	9.19
13A	0.50	5.18	0.19	0.98	0.30	7.15
14A	0.62	6.41	0.30	1.75	0.48	9.59
Average	0.76	7.92	0.25	1.51	0.44	10.82
SE	0.10	0.72	0.02	0.17	0.01	0.96

TABLE 3. Residues of DDT Metabolites and Isomers in White Croaker Flesh Plus Skin (ppm)

Sample	op'DDE	pp'DDE	op'DDT	pp'DDD	pp'DDT	Total DDT
1B	1.78	22.31	0.75	4.58	1.22	30.61
2B	2.06	20.19	0.73	2.98	1.36	27.32
3B	1.23	17.11	0.54	2.42	0.91	22.21
4B	0.70	16.67	0.42	0.87	0.83	19.49
5B	1.59	18.81	0.92	2.50	1.71	25.53
6B	0.71	10.28	0.27	1.90	0.61	13.67
7B	0.50	6.16	0.38	1.68	0.72	9.44
8B	0.55	8.29	0.42	1.58	0.47	11.31
9B	1.75	16.66	0.41	2.88	0.92	22.62
10B	0.46	7.24	0.48	1.36	0.53	10.07
11B	1.80	17.49	0.46	3.19	1.02	23.96
12B	1.14	12.85	0.34	2.85	0.78	17.96
13B	0.65	8.24	0.16	1.36	0.36	10.77
14B	0.91	5.39	0.42	2.52	0.94	10.18
Average	1.13	13.41	0.48	2.33	0.88	18.23
SE	0.15	1.53	0.05	0.26	0.10	1.95

Percentages of pp'DDE in samples analyzed during this study agree with values previously published. pp'DDE is the most persistent toxic metabolite of pp'DDT. Risebrough (1969) found 61 to 73% of DDT residues to be pp'DDE in marine fish. In our study the average value for Group A is 73.2% pp'DDE and 73.6% pp'DDE for group B.

We and others have analyzed white croakers from the Monterey, California area and have found low (<0.5 ppm) levels of DDT in the flesh of these fish (Shaw, 1972). The high (up to 30 ppm in our study) levels of DDT seem to be localized in the Los Angeles-Long Beach area.

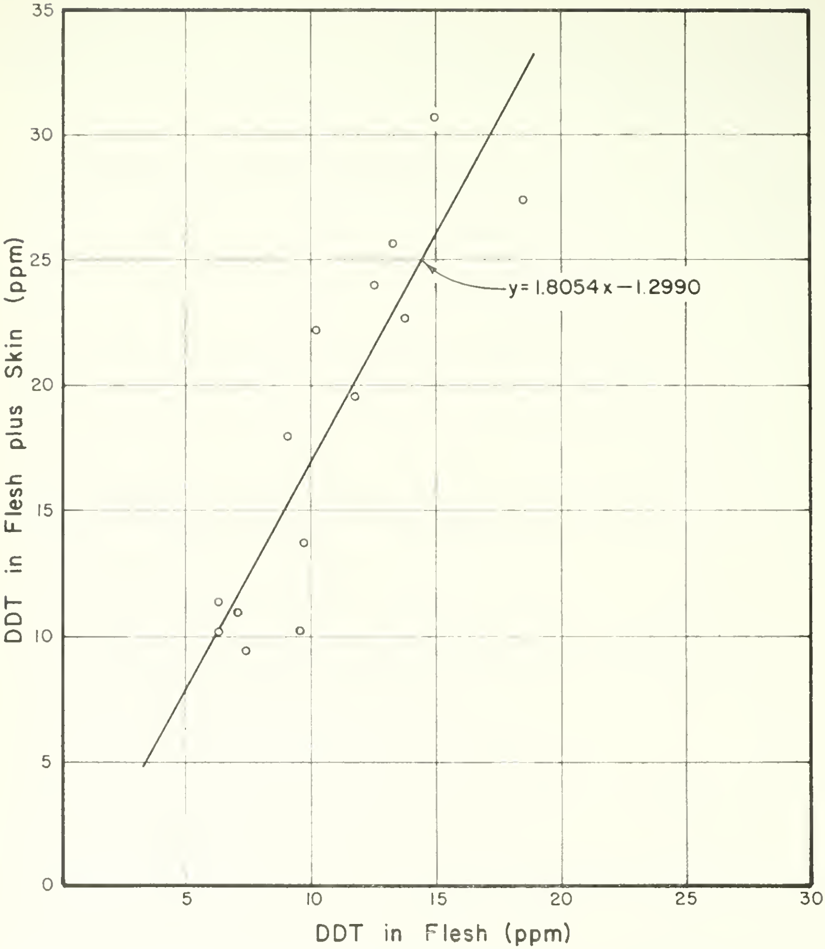

FIGURE 1. DDT residues in white croaker flesh plus skin versus DDT residues in white croaker flesh. N = 14, F = 46.3671, $r^2 = .7944$.

The white croaker is a fish of relatively minor commercial importance (Joseph, 1962. Roedel, 1953 and Gates, Calif. Dep. Fish and Game, pers. comm.). It could be a fish of importance as an indicator species regarding harbor area contamination since it is a resident continually exposed to the DDT contamination and should reflect this continuous exposure by levels of DDT in its flesh (Woodwell, 1971). However, it would be desirable to have more specific knowledge of the white croaker's range and food habits.

ACKNOWLEDGMENTS

The authors would like to express their thanks to Herman Fallscheer and Milton Luke of the Federal Food and Drug Laboratory in Los Angeles for their cooperation in running collaborative samples. Our

thanks go to all members of the Department of Fish and Game who assisted with collection of the fish and preparation of the samples for analysis and especially to Ralph Carpenter for his invaluable advice on the statistical analysis.

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CHARACTERISTICS OF THE FALL-RUN STEELHEAD TROUT (*SALMO GAIRDNERI GAIRDNERI*) OF THE KLAMATH RIVER SYSTEM WITH EMPHASIS ON THE HALF-POUNDER[1]

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Creel census data for the 1958, 1962, 1967, and 1968 Klamath River runs were analyzed to determine growth, age composition, sex ratios, maturity, migrations, food, feeding habits, and length-weight relationship of fall-run steelhead, particularly half-pounders, (defined here as steelhead 250–349 mm FL). These were in the 1/1, 2/1, and 3/1 age categories and were on their first upstream migration after only a few months in the ocean. Most half-pounders are immature, but probably return as mature steelhead after a second season in the ocean. Half-pounders, in contrast to mature steelhead, feed extensively on their first upstream migration. The sex ratio of all Klamath River fall-run steelhead is about 1:1. Condition factors increase in saltwater and decrease in fresh. Scale formation begins at about 30 mm.

INTRODUCTION

Fall-run steelhead trout of the Klamath River system provide an important sport fishery during August, September, and October. This fishery accounts for about five times the effort expended for the later-run (winter) steelhead (Fish and Wildlife Service, 1960). The early fall-run fishery is primarily for small steelhead commonly called "half-pounders" and is the most important of its type on the West Coast. Half-pounders are limited to the Klamath, Eel, and Rogue rivers, and to a lesser extent to a few other rivers in northern California and southern Oregon.

In this study, steelhead 250–349 mm (9.8–13.8 inches) FL are defined as half-pounders.

The purpose of this study was to determine the growth characteristics, age composition, sex ratios, maturity, migration characteristics, and food and feeding habits of Klamath River fall-run steelhead, particularly the half-pounder.

STUDY AREA

The Klamath River basin is in south central Oregon and northwestern California (Figure 1). In California, the basin includes portions of Modoc, Siskiyou, Trinity, Humboldt and Del Norte counties. In Oregon, it comprises portions of Lake, Klamath, Josephine, and Jackson counties. The area of the basin is approximately 10 million acres.

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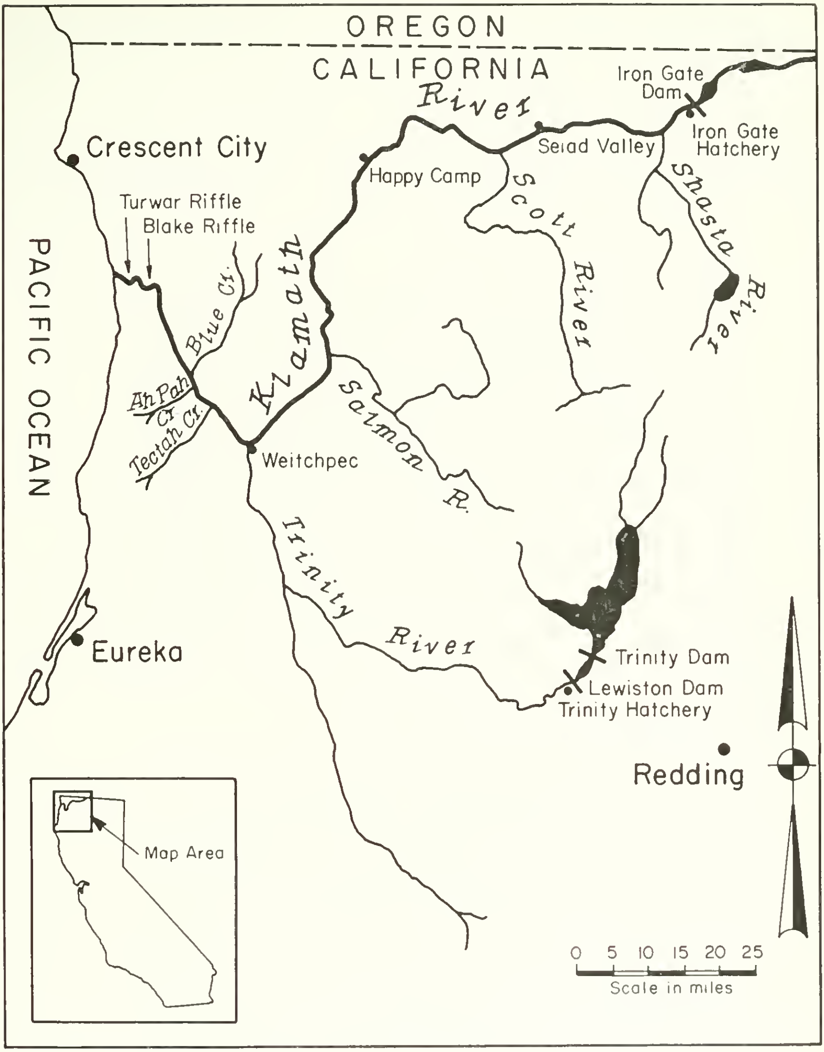

FIGURE 1. Klamath River drainage.

The main river within the basin is the Klamath, the second largest river in California, exceeded in size only by the Sacramento. The Klamath originates at Lake Ewana, near Klamath Falls, Oregon. From Lake Ewana it flows southwest for 263 miles to its mouth, 32 miles south of the Oregon-California boundary.

Iron Gate Reservoir is 190 miles upstream from the mouth, at which point the upstream migration of anadromous fish is blocked.

The largest tributary of the Klamath is the Trinity River. Two recently constructed reservoirs, Lewiston and Trinity, block the migration of anadromous fish into its upper reaches. Other major tributaries

are the Shasta, Scott, and Salmon rivers. Approximately 200 minor tributary streams complete the drainage system.

METHODS AND MATERIALS

Data from 618 returning fall-run steelhead were collected by creel census and hook and line in 1967 and 1968. Samples from 232 steelhead collected by creel census and hook and line in 1962 and 58 steelhead caught in fyke nets near Ah Pah Creek in 1958 were given to the authors. During 1967–68 additional data were collected from steelhead that had migrated to Iron Gate Hatchery on the upper Klamath River. In 1967 and 1968, juvenile steelhead were sampled by electrofishing from Blue and Tectah creeks, small tributaries of the lower Klamath. Data collected included some or all of the following: length and weight measurements, scale samples, gonad samples, and stomach samples.

All scales were read on a commercial scale reader using a magnification of 80×. Scales were read at least three times. If a fair degree of confidence concerning the age of a fish could not be established at the third reading, it was eliminated from the data. Three qualified persons read specified groups of scales to confirm our interpretations. General agreement was attained.

The principal criteria used to define annuli in the study were cutting or crossing-over of circuli, incompleteness of circuli, and narrowing of distance between circuli (Figures 2 and 3). One year's growth as represented on a scale was considered to be the time from the formation of the last circulus of an annulus to the formation of the last circulus of the succeeding annulus.

FIGURE 2. Scale of a 1/1 Klamath River half-pounder. Note the large amount of stream growth in the year of entrance to the ocean.

Ocean growth on steelhead scales was distinguished from stream growth by the increased spacing between the circuli. It was sometimes difficult to distinguish ocean growth from river growth, especially on the scales of larger steelhead.

In this study we used the method of aging steelhead devised by Shapovalov and Taft (1954). Briefly, this indicates years spent in the stream and ocean and, when applicable, the spawning history of the

fish. The number of years spent in the stream appears on the left-hand side of a diagonal line and the number of years in the ocean on the right-hand side of the line. For example, steelhead with an indicated age of 2/1 have spent 2 years in the stream, and 1 year in the ocean.

The majority of the steelhead sampled were captured during the fall months, well before they had completed their current year's growth. For the study, the year of capture is considered a full year's growth. For example, a 2/1 fish has been given an age of 3 years, even though its third year represents only a few months in the ocean.

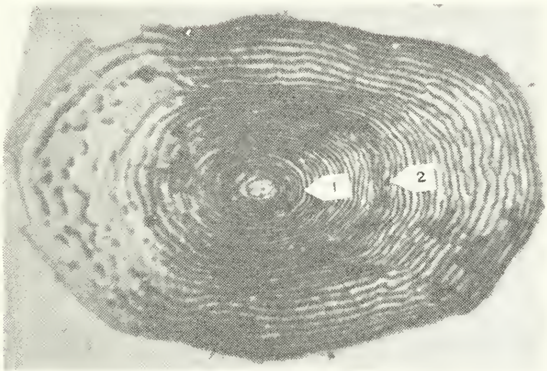

FIGURE 3. Scale of a 2/1 Klamath River half-pounder. Note the small amount of growth achieved during the first year of life.

The year of life in which steelhead smolts enter the sea usually includes both stream and ocean growth. For purposes of clarity and convenience, and because the greatest amount of growth is achieved in the ocean, a year of mixed stream and ocean growth has been indicated as ocean growth.

All readable scales were measured so that lengths at annuli and other positions of importance could be back-calculated.

All readable scales were examined to determine if spawning checks were present at annuli. In this study, an area of moderate to heavy lateral and anterior resorption is considered a spawning check. Small amounts of lateral resorption may appear at almost any annulus of the steelhead scale, but we believe that such resorption does not indicate a spawning-maturation check.

Stomach and gonad samples were analyzed by standard techniques. Temperature and flow data were obtained from the U. S. Geological Survey, Eureka, California. A computer program was used in the length-weight regression analysis (Swingle, 1964). The scale radius-length regression analysis was also computerized.

GROWTH CHARACTERISTICS

The relationship between fork length and weight of 532 Klamath River steelhead of several age categories was calculated for fish divided into 10 mm groups and for individual fish (Figure 4). The formula used was $W = aL^b$ or $\log W = \log a + b (\log L)$, where log

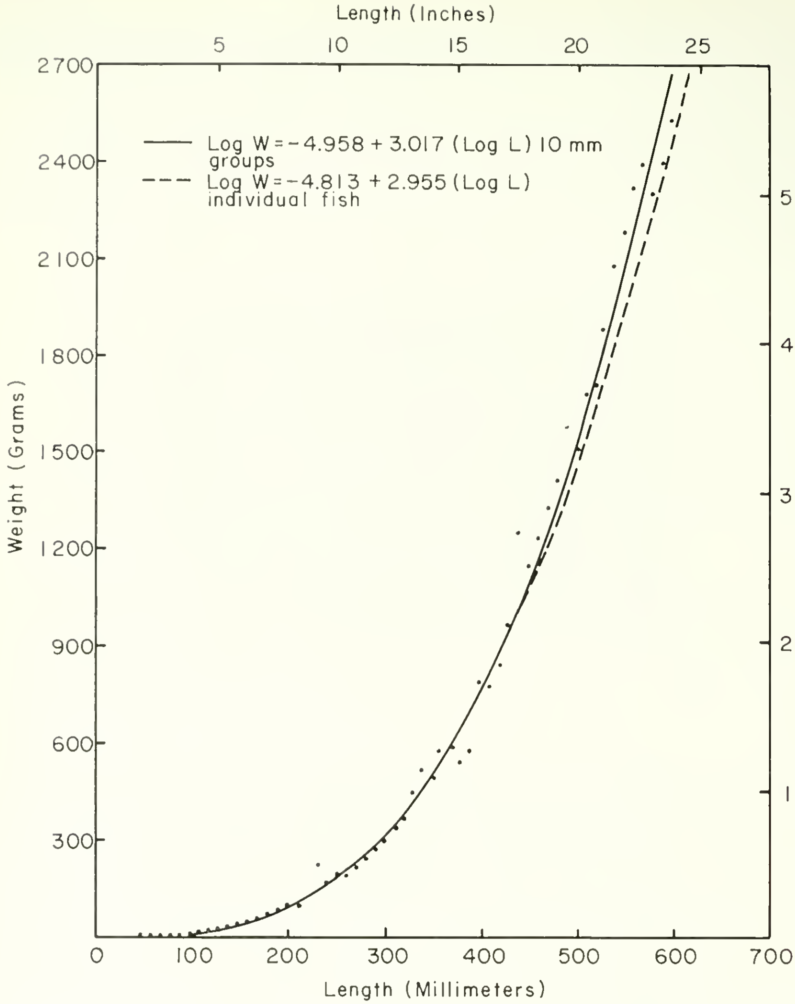

FIGURE 4. Relationship between fork length and weight of 532 Klamath River steelhead. The dots represent the average weights for the mid-points of 10 mm length intervals.

a = —4.958 and b = 3.017 for the fish divided into 10 mm length groups. For individual fish, it was log a = —4.813 and b = 2.955.

A scale radius-length regression analysis performed on 712 fall-run steelhead gave an intercept of 30.1 mm assuming a linear relationship. Snyder (1925), in a study of the Eel River half-pounder, inferred that scales first appear when the fish is about 30 mm long. Sumner (pers. comm.) earlier used a 38 mm intercept for back-calculating lengths of steelhead, but he is currently using a 35 mm intercept in a study by the Oregon Game Commission of Rogue River summer steelhead.

Lengths by age category were determined for Klamath River stream steelhead (Table 1). The differences in size of Klamath River stream steelhead within the same age category may be accounted for by different growth rates and the prolonged spawning season of steelhead which leads to different hatching and emerging times.

TABLE 1. Means and Ranges of Fork Lengths of Klamath River Stream Steelhead Collected in 1962, 1967, and 1968 Before Completion of Their Current Year's Growth

Age category	Mean fork length (mm)	Range of fork lengths (mm)
1/0	79 (57)*	52–115
2/0	150 (79)	108–195
3/0	218 (7)	175–274

* Sample size in parentheses.

Lengths by age category were determined for Klamath River ocean steelhead (Table 2). The values are similar to those found by Snyder (1925) for 18 Klamath River steelhead. The means and ranges of fork lengths for males and females showed no appreciable differences.

TABLE 2. Length Measurements by Age Category. Means and Ranges of Fork Lengths (mm) of Klamath River Ocean Steelhead From the 1958, 1962, 1967, and 1968 Runs. Measurements Taken Before Completion of Current Year's Growth

	Year sampled				
Age category	1958	1962	1967	1968	Total
1/1	279 (3)* / 279	285 (43) / 252–340	287 (2) / 275–298	293 (26) / 260–370	287 (74) / 252–370
1/2	436 (8) / 368–559	458 (7) / 417–553	486 (15) / 448–517	---	466 (30) / 368–559
1/3	---	542 (1) / 542	585 (1) / 585	---	564 (2) / 542–585
2/1	338 (28) / 267–406	312 (92) / 263–420	360 (34) / 308–429	328 (48) / 285–409	327 (202) / 263–429
2/2	533 (3) / 508–559	427 (4) / 405–453	521 (37) / 455–584	517 (8) / 456–586	514 (52) / 405–586
3/1	381 (6) / 356–406	357 (6) / 289–451	404 (14) / 332–468	329 (3) / 285–354	382 (29) / 285–468
3/2	---	---	524 (2) / 521–526	---	524 (2) / 521–526

* $\frac{\text{Mean}}{\text{Range}}$ Sample size in parentheses.

Means and ranges of length were determined for Klamath River steelhead sampled at Iron Gate Hatchery during the winter of 1967–68. A comparison of the lengths of steelhead sampled at the hatchery with the lengths of other Klamath River steelhead of comparable ages indicated that they did not differ markedly.

Means and ranges in length at previous ages were back-calculated for Klamath River ocean steelhead (Table 3). We found that lengths at annuli for steelhead from the 1962 run were generally less than those for steelhead from the 1958, 1967, and 1968 runs. Discrepancies between lengths of stream steelhead (Table 1) and corresponding back-calculated lengths of ocean steelhead (Table 3) can best be explained by the fact that the stream fish had not completed their year's growth when collected. The lengths of several 2/0 fish collected at or near

TABLE 3. Back Calculated Lengths by Age Category. Back Calculated Means and Ranges of Fork Lengths (mm) at Annuli for Klamath River Steelhead From the 1958, 1962, 1967, and 1968 Runs Combined

	Annulus				
Age category	1	2	3	4	5
1/1	118 (74) 90–165	287 (74)* 252–370			
1/2	139 (30) 100–185	329 (30) 250–395	466 (30)* 368–559		
1/3	120 (2) 110–130	315 (2) 310–320	490 (2) 470–520	564 (2)* 542–585	
2/1	92 (202) 60–145	169 (202) 105–280	327 (202)* 263–429		
2/2	104 (52) 60–145	192 (52) 132–290	383 (52) 300–460	514 (52)* 405–586	
3/1	93 (29) 65–140	168 (29) 105–230	242 (29) 155–320	382 (29)* 285–468	
3/2	98 (2) 80–115	163 (2) 135–190	265 (2) 220–310	435 (2) 420–450	524 (2)* 521–526

* Length at time of capture (and before annulus formation). Others are back-calculations giving lengths at time of annulus formation.

annulus formation (mid-January) were in close agreement with back-calculated lengths of 2/1 and 2/2 steelhead.

A size group frequency distribution was determined for Klamath River fall-run steelhead (Table 4). Half-pounders (250–349 mm size category) consisted only of 1/1, 2/1, and 3/1 individuals. Some fish of these ages were found within larger size categories also. These age groups migrated upstream in the same year that they entered the ocean. Thus the small-sized Klamath River steelhead, commonly called

"half-pounders", are fish which had been in the ocean only a very short period of time and had achieved little ocean growth before beginning their first upstream migration.

TABLE 4. Size-Group Frequency Distribution of Klamath River Steelhead From the 1958, 1962, 1967, and 1968 Runs

Age category	Size group (mm fork length)		
	250–349 (half-pounder)	350–449	≥450
1/1	71	2	--
1/2	--	10	20
1/3	--	--	2
2/1	152	50	--
2/2	--	3	49
3/1	8	18	3
3/2	--	--	2

AGE COMPOSITION

Most of our data were collected by creel census during the fall of the year so the age composition of steelhead runs occurring later cannot be inferred. The majority of the steelhead studied were in the 2/1 category. Fish in the 1/1 category were moderately numerous in 1962 and 1968, but were almost lacking in 1967. Notable were the large numbers of 2/2 steelhead in 1967 and lack of 1/2 fish in 1968 (Table 2).

Shapovalov and Taft (1954), Maher and Larkin (1954), and others reported that the age composition of steelhead runs within a given drainage varies from year to year. Although the age composition of Klamath River steelhead no doubt varies from year to year, the differences observed in the 1967 and 1968 runs are atypical. It was apparent from conversations with long-time Klamath River fishermen that the 1967 run lacked normal numbers of half-pounders and that the 1968 run contained very few larger, older fish. This is interesting since the 2/1 half-pounders of 1967 and 2/2 steelhead of 1968 were both of the 1965 year class.

The winter of 1964–65 in northern California was a time of exceptionally high water and heavy flooding. The effects of high water on steelhead production for the year are not known. It is possible that reduced food supplies and abnormal temperature patterns affected the survival of steelhead of the 1965 year class.

MIGRATION AND MOVEMENT

The size of Klamath River steelhead at the time of entrance to the ocean was calculated at between 187 and 210 mm for 1-year-old smolts, 199 and 215 mm for 2-year-old smolts, and 247 and 280 mm for 3-year-old smolts (Table 5 and Figure 5). Riikula (Oregon Game Commission, pers. comm.) states that the average length of Rogue River steelhead at entrance to the sea was between 191 and 241 mm.

Examination of Klamath River steelhead scales revealed that 1/1 fish do not migrate as rapidly to the ocean after formation of their first annulus as do 2/1 steelhead after formation of their second annulus.

TABLE 5. **Calculated Means and Ranges of Fork Length at Entrance to the Ocean of Klamath River Steelhead From the 1958, 1962, 1967, and 1968 Runs**

Age category	Fork length (mm)	
	Mean	Range
1/1	187 (74)*	140–265
1/2	200 (30)	140–265
1/3	210 (2)	210
2/1	199 (202)	130–280
2/2	215 (52)	150–290
3/1	217 (29)	175–320
3/2	280 (2)	250–310

* Sample size in parentheses.

This conclusion is based on the observation that more stream growth is usually present in the year of seaward migration on 1/1 scales than on 2/1 scales (Figures 2 and 3). It is interesting that 3/1 Klamath River steelhead scales show little, if any, stream growth after formation of their third annulus and, therefore, enter the ocean earlier than do 2/1 fish.

Neave (1949), Maher and Larkin (1954), Shapovalov and Taft (1954), and Chapman (1958), found that the majority of steelhead smolts enter the ocean during March through May. The majority of Klamath steelhead enter the ocean in mid-April or early May and many return in September. This indicates an ocean growth rate for 2/1's of 130 mm for 4 months, or about 30 mm per month.

The length of 1/1 steelhead at their first stream annulus is greater than the lengths of 2/1 and 3/1 fish at the same annulus (Figure 5). Apparently, 1/1 fish have a greater stream growth rate than 2/1 fish and are able to achieve smolt size in their second year, but are smaller upon entering the ocean than are the 2- and 3-year-old smolts. In addition they go to sea later in the year than the 2/1 and 3/1 fish, but return at about the same time and have not achieved as much ocean growth. They, therefore, are of smaller size than 2/1 and 3/1 fish.

There is little difference between the lengths of 1/1, 2/1, and 3/1 steelhead and the back-calculated lengths of adult steelhead of similar freshwater life histories. This was true of the 1965 year class sampled in consecutive years (Table 6). Thus, we feel the Klamath River half-pounder returns the following year as a large mature steelhead.

We were not able to ascertain why half-pounders spend only a few months in the ocean before beginning their first upstream migration. Studies by Maher and Larkin (1954) and Sumner (1945) show that steelhead from the Chilliwack River and Tillamook County streams, with few exceptions, spend 2 years at sea before commencing their first upstream migration. Whitt and Pratt (1955) report that most Clearwater River steelhead spend 1 year in the ocean before beginning their first upstream migration. A great proportion of Waddell Creek steelhead return to the river after having spent 1 year at sea (Shapovalov and Taft, 1954. Hallock, Van Woert, and Shapovalov (1961) found that most Sacramento River steelhead spend 1 or 2 years in salt water.

Half-pounders were caught primarily in the early part of the 1967 fall run, while larger steelhead were taken later in the run. In 1968,

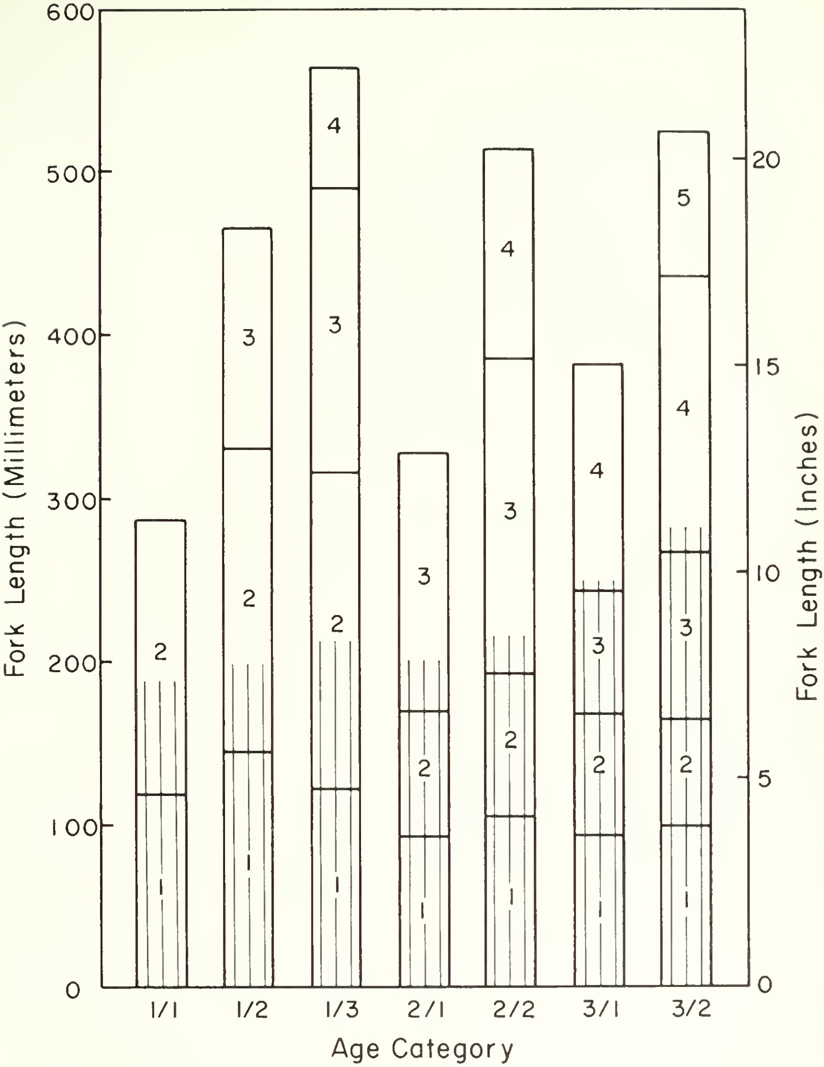

FIGURE 5. Mean fork lengths at annuli for Klamath River steelhead from the 1958, 1962, 1967, and 1968 runs combined. The striped areas of the bars represent stream growth and the clear areas ocean growth.

essentially all half-pounders at Blake Riffle were caught by early September. Bailey (1952) computed the mean fork lengths for steelhead caught at Blake and Turwar riffles for 7 days between August 26 and October 10, 1951. His data show that the mean lengths of the fish caught increased as the season progressed.

Although no catch-per-unit effort data were obtained during the study, it was observed that the best angling at Blake Riffle, occurred

TABLE 6. Means and Ranges of Fork Lengths (mm) at Annuli for the 1965 Year Class of 2/1 and 2/2 Klamath River Steelhead Sampled in 1967 and 1968, Respectively

Age category	Annulus 1	Annulus 2	Annulus 3	Annulus 4
2/1	91 (34)* / 70–125	191 (34) / 140–280	360† (34) / 308–429	
2/2	100 (8) / 80–115	191 (8) / 150–260	390 (8) / 340–450	517† (8) / 456–586

* Mean / Range. Sample size in parentheses.
† Length at capture, measurements taken before completion of current year's growth.

between September 1–10 in 1967 and August 21–25 in 1968. U. S. Geological Survey temperature and flow records of the lower Klamath River for 1967 and 1968 were examined for relationships between temperature and flow and times of steelhead movement, specifically September 1–10, 1967 and August 21–25, 1968. An average drop of 3 F in the daily maximum and minimum temperatures did occur during the 1968 period. A similar correlation was not obvious in 1967. No correlation was apparent between water discharge and fall-run steelhead movement in the lower Klamath. Water temperatures in the lower Klamath generally range in the low 70's for the period of mid-August to mid-September. A few days of cloudy weather inland can result in a few degrees drop in temperature on the lower river, possibly enough to stimulate fish movement. The average late summer, early fall discharge in the lower Klamath ranges from 2,200 cfs to 4,400 cfs, but fluctuates little until the rainy season begins, usually mid-October. Discharge, therefore, probably is not as important a factor as temperature in stimulating fall-run steelhead movement on the lower Klamath. This is not the case for small streams. In Waddell Creek, a small central California coastal stream, Shapovalov and Taft (1954) point out the importance of stream flow in stimulating upstream migration.

The migration patterns of fall-run steelhead, particularly half-pounders, after entrance into the river are largely unknown.

Persons associated with the Klamath River fishery state that most half-pounders do not migrate above Seiad Valley, 130 miles from the mouth of the river. Riley and Estey (California Department of Fish and Game, pers. comm.) have not observed large numbers of half-pounders at Iron Gate and Trinity River hatcheries. Lanse (pers. comm.), from observations and interpretation of data collected during creel surveys on the upper Klamath in 1967 and 1968, believes that half-pounders do not occur in great numbers above Happy Camp. The Salmon River has a sizeable half-pounder run. People living in the Scott River area reported that the half-pounder run is not large in that tributary.

CONDITION

Average condition factors of Klamath River steelhead were calculated for the 1962, 1967, and 1968 runs (Table 7). The lower condition factors of steelhead from the upper Klamath and Trinity rivers are not surprising since upstream migration is demanding and draws upon the energy reserves of the fish. Many of the scales examined showed small amounts of marginal resorption at annuli. According to Chapman (1958), this indicates the fish were losing or just maintaining their weight.

TABLE 7. Average Condition Factors of Klamath River Steelhead From the 1962, 1967, and 1968 Runs

Age category	Location		
	Lower Klamath†	Upper Klamath‡	Trinity River
1/1	1.16 (23)*	1.14 (8)	1.01 (25)
1/2	1.31 (17)	1.14 (5)	1.26 (1)
2/1	1.21 (90)	1.15 (10)	1.01 (39)
2/2	1.28 (32)	----	0.98 (1)
3/1	1.28 (12)	1.07 (2)	1.10 (1)

* Sample size in parentheses.
† Mouth of Klamath to Weitchpec.
‡ Weitchpec to Iron Gate Reservoir. Includes a few fish sampled at Iron Gate Dam.

Condition factor: $K = \frac{1{,}000 \text{ weight (g)}}{\text{length (mm)}^3}$

Trinity River 1/1 and 2/1 steelhead have lower average condition factors than the same age categories of steelhead taken from the upper Klamath. Many of the Trinity River samples were obtained later in the year than were samples from the upper Klamath. Further investigation may show, however, that the difference in condition factors is an indication of a difference in productivity between the two rivers.

The average condition factor of 55 1/0 juvenile steelhead taken from the lower Klamath River was 1.35. For 79 2/0 juvenile steelhead taken from all sections of the river the average condition factor was 1.29.

SEX RATIO

The sex ratios for steelhead captured on the lower Klamath were as follows: total all years, 120 males to 129 females, 21 undetermined; 1962, 32 males to 35 females, 1 undetermined; 1967, 60 males to 60 females, 9 undetermined; 1968, 28 males to 34 females, 11 undetermined. Many of the fish for which sex could not be determined showed little or no gonad development. We believe that many of these were immature males. Data were insufficient to allow meaningful determination of sex ratios by age category.

MATURITY

In this study, steelhead with gonads weighing 1 g or less were considered immature. We felt this was below the gonad weight which divides mature and immature steelhead. We prepared a gonad weight frequency distribution for Klamath River steelhead (Table 8). Half-

TABLE 8. Gonad Weight Frequency Distribution of Klamath River Steelhead From the 1962, 1967, and 1968 Runs

Age category Year sampled*	Weight of gonads in grams				
	1.0	1.1-10.0	10.1-25.0	25.1-50.0	51.0-75.0
1/1					
1962	13/23†	---	---	---	---
1967-68	8/13	---	---	---	---
1/2					
1962	2/0	1/0	0/1	---	---
1967-68	2/1	1/3	3/4	1/2	---
2/1					
1962	31/16	0/1	---	---	---
1967-68	6/39	2/1	---	1/0	---
2/2					
1962	2/1	0/1	---	---	---
1967-68	4/0	5/2	7/3	2/6	2/1
3/1					
1962	1/2	---	---	---	---
1967-68	3/1	2/4	1/1	---	---
3/2					
1962	0/0	---	---	---	---
1967-68	---	---	0/1	0/1	---

* The 1962 samples were weighed as fresh material in the field; those of 1967 and 1968 were weighed as preserved material in the laboratory after blotting to remove excess preservative.
† Male/female.

pounders accounted for the majority of the 1/1 and 2/1 fish and only three half-pounders possessed gonads weighing more than 1 g. Everest (1970) examined gonads from 80 half-pounders netted on the lower Rogue River for stage of maturity. Only three of 37 Rogue River males examined (8%) were maturing and these averaged slightly more than 15 inches (380mm) FL. No females were maturing. Everest defines a ''half-pounder'' as a fish which has spent 1, 2, or 3 years rearing in freshwater and less than one year at sea before making its first upstream migration, and states that such fish are less than 16 inches in length. Data from a small sample from the Klamath River indicated that half-pounder gonads collected in late fall and early winter months had not increased significantly in size.

The percentage of Klamath River half-pounders on a spawning migration needs further investigation.

Our data indicate that the majority of Klamath River fall-run steelhead reach sexual maturity at age four or older, although considerable variation exists. Many of the steelhead scales from older age categories (1/2, 2/2, 3/2) collected in the winter of 1967 at Iron Gate Hatchery showed the beginnings of heavy resorption during their current year's growth. However, none of the 1/1 and 2/1 fish collected from the Klamath River or the hatchery showed evidence of heavy resorption on any part of their scales. Only two of the 2/2 steelhead scales showed evidence of heavy lateral and anterior resorption at the third (2/1) annulus indicating they had spawned. None of the scales of 1/2 fish showed resorption at the 1/1 annulus.

Size as well as age apparently influences time of maturation. Many of the 1/2 steelhead studied possessed gonads weighing more than 1 g (Table 8). They had achieved considerable size after spending 2 years in the ocean. In our study all 2/1 steelhead larger than half-pounder size also possessed gonads weighing more than 1 g.

Our data indicate that there were two second spawners in the steelhead sampled. Shapovalov and Taft (1954), Chapman (1958), Whitt and Pratt (1955), Maher and Larkin (1954), and Hallock, Van Woert, and Shapovalov (1961), reported 82.8%, 83–88%, 98%, 95%, and 83% were first time spawners in their respective steelhead runs.

FOOD AND FEEDING HABITS

Regarding the feeding habits of steelhead, Snyder (1933) states: "On entering the streams their stomachs are usually empty, and they seem to remain so while they are in the estuaries. A little farther upstream their appetites appear to return, and their behavior is governed accordingly."

Snyder's statement describes well our findings concerning the feeding habits of Klamath River steelhead. Stomach samples, when not empty, from the lower Klamath contained relatively small amounts of food material (Table 9). None of the stomachs were full, as was the case for many of the fish stomachs sampled from the upper Klamath.

TABLE 9. Percentage of Klamath River Steelhead From the 1962, 1967, and 1968 Runs With Food Materials in Their Stomachs

	Area			
Size group fork length (mm)	Lower Klamath*	Upper Klamath†	Trinity River	Total
250–349 (half-pounders)	49 (139) ‡	83 (65)	88 (75)	67 (279)
350–449	35 (51)	55 (10)	87 (8)	41 (69)
≥450	27 (81)	33 (3)	0 (1)	27 (85)
Totals	40 (271)	77 (78)	87 (81)	55 (433)

* Mouth of Klamath to Weitchpec.
† Weitchpec to Iron Gate Reservoir.
‡ Sample size in parentheses.

It is interesting that half-pounders feed more than do larger steelhead. Sixty-seven percent of the fish under 350 mm had food in their stomachs compared to only 44% for those fish 350–449 mm and 27% for those fish over 449 mm. A higher percentage of large steelhead, in contrast to half-pounders, are ripe or ripening and on a spawning migration. Lanse (pers. comm.) states that the stomachs of ripe Klamath River steelhead frequently are empty.

We determined the numbers of Klamath River steelhead from the 1967 and 1968 runs containing specified food material in their stomachs. Trichoptera larvae were consumed by more fish than were other food

materials (Table 10). Shapovalov and Taft (1954) found Trichoptera larvae to be the most important food item of Waddell Creek stream steelhead. Cowichan River steelhead (255 to 510 mm long) also had a higher incidence of Trichoptera larvae in their stomachs than other food items (Shapovalov and Taft, 1954, citing Idyll, 1942). This probably does not indicate food preference but rather food availability. It appeared that many of the fish had simply "scooped up" a mass of food materials often mixed with small stones, sticks, bird feathers, or other miscellaneous material.

TABLE 10. Numbers of Klamath River Steelhead From the 1967 and 1968 Runs Containing Specified Food Materials in Their Stomachs

		Size group (mm)			
Food material	Stage*	250–349 (half-pounder)	350–449	≥450	Total
Diptera	I	13	0	1	14
Lepidoptera	I	6	1	0	7
Hymenoptera	M	1	0	0	1
Ephemeroptera	I	17	3	4	24
Odonata	I	4	0	0	4
Plecoptera	I	17	3	1	21
Hemiptera	M	2	0	0	2
Coleoptera	M	1	0	0	1
Trichoptera	I	30	3	1	34
Gastropoda	--	4	1	1	6
Pelecypoda	--	1	0	0	1
Annelida	--	2	0	0	2
Crustacea	--	0	0	1	1
Fish	--	1	1	1	3
Salmon eggs	--	11	4	10	25

* I, immature; M, mature.

SUMMARY

1) For purposes of this study the half-pounder is defined as a steelhead 250–349 mm FL. The majority of those aged were in the 2/1 category, all the remainder were either 1/1 or 3/1.

2) Half-pounder steelhead are limited to rivers of northern California and southern Oregon, principally the Klamath, Eel and Rogue. The fishery for half-pounders on the Klamath River is the most important of its type on the West Coast.

3) Biological data from over 900 Klamath River stream and returning (ocean) steelhead were obtained during 1958, 1962, 1967, and 1968 by creel census, hook and line, and electrofishing.

4) Scales were used for age determination; all scales were measured so the size of the fish at annulus formation and entry into the ocean could be calculated.

5) Stomach and gonad samples were analyzed by standard techniques.

6) Length-weight relationships are presented for fish divided into 10 mm length groups and for individual fish.

7) The calculated fish length at the time of scale formation is 30.1 mm.

8) Mean lengths by age category of ocean steelhead were similar to those found in a previous Klamath River steelhead study and were similar to those from fish sampled at Iron Gate Hatchery.

9) The back-calculated sizes at time of entrance to the ocean for ocean steelhead were as follows: 1-year-olds, 187–210 mm; 2-year-olds, 199–215 mm; and 3-year-olds, 247–280 mm. Older smolts apparently migrate to the sea earlier in the year than the younger ones.

10) Based on back-calculations, steelhead from the 1962 run grew more slowly than those from other runs sampled.

11) Actual lengths of several 2/0 steelhead taken near the time of annulus formation were in close agreement with the back-calculated lengths of 2/1 and 2/2 fish at the time of their second annulus formation.

12) There were no good correlations between water temperature or flow, and peak runs of Klamath River steelhead.

13) The distribution of half-pounders in the Klamath River extends from the mouth upstream to about Seiad Valley. The Salmon River has a sizeable half-pounder run.

14) Condition factor of Klamath River steelhead decreases with time in freshwater.

15) The sex ratio of Klamath River steelhead is approximately one-to-one.

16) The Klamath River half-pounder is small because it remains only a short time in the ocean before makings its first upstream migration. Gonad examinations indicate that it enters freshwater on a non-spawning run, excepting perhaps for a small percentage of males. It returns to the ocean and later makes a second upstream migration as a larger mature steelhead. Most Klamath River steelhead reach sexual maturity at age four.

17) Stomach analyses indicate half-pounder steelhead feed extensively while large maturing steelhead do not. Trichoptera larvae were the most common food item noted in stomach samples.

ACKNOWLEDGEMENTS

The authors wish to make special acknowledgement to the following people: Francis H. Sumner, Scale Analyst, Oregon Fish Commission, and Leo Shapovalov, Senior Fishery Biologist, California Department of Fish and Game, for helping in interpreting scale patterns; James W. Burns, Associate Fishery Biologist, California Department of Fish and Game, for data from the 1962 Klamath River steelhead run; Roger Lanse, Assistant Fishery Biologist, California Department of Fish and Game, for collection of reproductive organs from steelhead in the upper Klamath in 1967; Jim Riley, Hatchery Manager I, for use of personnel and facilities to collect scale samples from steelhead at Iron Gate Hatchery; Thomas E. Neenan, District Ranger, Klamath National For-

est, and James E. Carrier, District Ranger, Six Rivers National Forest, for collection of steelhead stomach samples in 1967 and 1968; Charles Bloom, Librarian III, Humboldt State College, for collection of scale samples from Trinity River steelhead; and Gary Tucker and other members of the North Coast Fly Fishermen for their help during many phases of the study.

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MORTALITY AND SURVIVAL RATES OF TAGGED LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*) AT MERLE COLLINS RESERVOIR[1]

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A tagging study from 1965 through 1969 revealed that exploitation rates of largemouth bass increased after the first season following impoundment, reaching a high of 0.65 in 1968 and 1970. Annual survival rates generally increased and stabilized near 0.20. Natural mortality declined. A combination of the highest reported exploitation rates, reduced annual catches, lowered catch/hour, increased bluegill populations, and competition with smallmouth bass and threadfin shad indicate possible continued depletion and overexploitation of largemouth bass.

INTRODUCTION

The number of low- and mid-elevation warmwater reservoirs in California is increasing rapidly. Potentially, these impoundments could satisfy the demands of an increasing number of anglers for quality fishing opportunities. Unfortunately, fish yields in these lakes, as in other impoundments throughout the world, are initially high but subsequently decline. Knowledge of annual harvest, mortality, and survival rates, as well as other catch statistics of the fishery, is necessary to interpret changes in the fishery and to develop appropriate management techniques. With the exception of Sutherland Lake (LaFaunce, Kimsey, and Chadwick 1964) past tagging studies in California to determine mortality and survival rates of largemouth bass have centered on older reservoirs and natural lakes (Fisher 1953; Kimsey 1957; Rawstron 1967). With the impoundment of Merle Collins Reservoir in 1964, a broad investigation to monitor the changes in fish yields was begun. As part of this investigation, a tagging study was initiated to estimate annual mortality and survival rates of the largemouth bass, the lake's chief predator and most popular game fish, during the years following impoundment. This report principally presents estimates of the above statistics from 1965 through 1970, but also draws on information derived from other portions of the investigation to indicate possible overexploitation of largemouth bass.

DESCRIPTION OF STUDY WATER

Merle Collins Reservoir is a typical steep-sided, fluctuating irrigation impoundment on French Dry Creek about 20 miles east of Marysville, California. It has a highly irregular shoreline with many coves. All trees greater than 2 inches in trunk diameter were removed, but

[1] Accepted for publication December 1971. This work was performed as part of Dingell-Johnson Project California F18R, "Experimental Reservoir Management", supported by Federal Aid to Fish Restoration funds.

much brush remained, creating excellent bass habitat. With a surface elevation of 1,183 ft at maximum operating pool, the surface area is 995 acres and gross pool storage is 57,000 acre-ft. Water was first impounded in November 1964.

During the warmest part of the year, when air temperatures are near 100 F in the daytime, surface water temperatures are in the low 80's and just before fall overturn the thermocline is depressed to depths between 45 and 50 ft. The entire epilimnion is well oxygenated throughout the warm months. Other aspects of the fishery are presented by Hashagen (MS). L. L. Chamberlain (MS) describes the limnology more fully.

The lake was opened to angling on June 1, 1965 and closed on November 1. In 1966 it was open from March 1 to November 1. Since March 1, 1967, the lake has remained open all year.

METHODS AND MATERIALS

Most fish were captured for tagging by electrofishing with a 230-V DC, 2,500-watt Homelite 24D230–1 generator coupled to a pulsator. Pulse rates and duty cycles were generally set at 60 pulses per second and 60%, respectively. The remaining fish were caught by angling. Most were captured at night on weekdays during the spring, held in live cages overnight, and tagged the following day. They were then redistributed systematically along the same shoreline where they had been caught. Tagging usually coincided with the beginning of bass spawning seasons and the onset of the best angling period. Angling pressure on weekdays during this period was light. Tagging operations usually lasted less than 2 weeks.

All fish were tagged with disk dangler (modified Atkins) tags. This tag has been used successfully for largemouth bass in California (Kimsey 1956; LaFaunce et al. 1964; Rawstron 1967; Rawstron 1971). They were attached with tantalum or stainless steel wire, 0.020 inch diameter. The two wire types have been shown to be equally efficient on striped bass (*Morone saxatilis*) by Chadwick (1963), while tantalum wire has proved successful on both largemouth and smallmouth bass (*Micropterus dolomieui*) (Rawstron 1967). They were placed midway between the first dorsal fin and the lateral line under the longest spine, using the technique described by Chadwick (1963). Tags used for mortality estimates were numbered serially and most bore the inscription, "California Fish and Game, Sacramento, Calif. $5 reward". Some, however, had the same legend but offered a $1 reward. Tags were made of laminated cellulose nitrate disks .040 inch thick and either 1 cm or $\frac{1}{2}$ inch in diameter.

All bass more than 8 inches fork length were tagged. The goal was to tag 100 fish each year. During 1966 only 34 bass were tagged because of frequent breakdowns of the electrofishing gear.

Posters advertising the program were placed in conspicuous locations around the lake. These same posters and franked envelopes for tag returns were placed with nearby local businesses and at a creel census station. A commendation card, the appropriate reward, and a letter explaining the program objectives were sent to all anglers returning tags.

A creel census clerk was stationed at the only entrance to the lake on all weekends and holidays as well as two rotating weekdays each week to examine all catches. The data obtained provided estimates of catch rates, annual harvest in numbers and weight, mean length and weight, catch per hour, and fishing effort. Although the census clerk did not recover tags, he did provide information to anglers on the goals of the study, thereby further increasing publicity. In addition, he recorded the serial number of tags seen in the census.

Survival, mortality, and exploitation rates were estimated from mail recoveries of $5 and $1 reward tags except in 1965, when only non-reward tags were used. Ricker's (1958) small sample formula (formula 5.2) was used to estimate survival, which was assumed to be variable. Weighted mean rates of exploitation were derived from his formula 4.5. First-year returns included all tags returned from fish caught 0 through 365 days after tagging. Second-year returns were those from fish captured 366 through 730 days after tagging, etc. Returns from $1 and $5 reward tags were combined for mortality estimates in 1966 and 1967, since no significant differences were noted in their return (Rawstron 1972).

RESULTS

Validity of Estimates

Although no reward tags were used in 1965, the effect of nonreporting (Ricker 1958: Type A error) which affects only the rate of fishing was reduced for this year by correcting returns of nonreward tags by the mean non-response of 0.34 measured in a companion study (Rawstron 1972). Other sources of Type A error were considered negligible. We assumed that all $5 reward tags were returned. Probably not all $5 reward tags were returned in all years, but we believe that these were few and produced only a slight underestimate. Furthermore, all reward tags seen and recorded in the 1968 creel census were returned by mail for the reward and lend further support to the assumption of low bias. Since no bass were recovered with scars from tag shedding, and no dead bass were found shortly after tagging, errors from these sources were considered negligible.

Neither abnormal behavior nor increased vulnerability due to tagging were apparent. Tagged fish redistributed themselves rapidly. We assumed they did so in proportion to the local abundances of bass. Thus, we considered Type C error to be negligible also, with no large effect on rate of fishing or total mortality.

Type B errors which might have overestimated the total annual mortality and natural mortality rates were more difficult to assess. In 1965, 20 tagged bass held in a trap measuring 16 x 16 x 8 ft for 16 days were all released in good condition with no mortality. All tags were in proper position, with no evidence of imminent shedding. Tags from this group were subsequently recovered throughout a 5-year period. Aquarium tests (Kimsey 1956) and field tests on bass at Clear Lake (Kimsey 1957) showed this same tag had long retentivity, had caused little mortality, and was not shed rapidly. Moreover, the present study indicated that the annual expectation of death due to natural causes declined, and stayed relatively constant during the study period, while total annual mortality varied slightly, suggesting that losses of tags or

extra deaths among tagged fish did not occur at a steady instantaneous rate. Rate of tag loss may accelerate after the first year, but the evidence from long-term returns is against any serious Type B error. Chadwick (1968), using the same tag on striped bass, reached a similar conclusion.

Estimated survival rate of bass for 1965 was probably too low and did not represent the true rate for the whole adult bass population. Fish of the 1964 year class had a mean fork length of 4.9 inches in 1965 (unpublished data). They were very abundant and only those over 8.0 inches were tagged. Bass of this year class grew slowly and reached a mean length of 8.4 inches in the spring of 1967. Therefore, in 1965 the criterion of tagging only bass over 8.0 inches, which were the fastest growing fish of the 1964 year class, created a bias which led to an underestimate of the true rate and only estimated survival of tagged fish over 8.0 inches. Moreover, this year class dominated the bass fishery for 3 years, contributing up to 90% of the total bass catch through 1967 (Hashagen MS), indicating that survival was higher for the whole population.

The longer open season in the latter year of the study probably contributed to the rise in exploitation rates, although in 1967, when the lake was open only 9 months, exploitation approached its maximum.

MORTALITY ESTIMATES

Mean fork length of tagged bass ranged from 9.1 inches in 1968 to 12.4 inches in 1966 and 1967 (Table 1). Anglers returned 333 (77.1%) of the reward tags issued over the entire study period (Table 2). This figure does not include nonreward tags issued in 1965.

First-year harvest rates (u_1) for bass of different length classes were highly variable and no consistent trend was apparent (Table 3). Sample size was small in some years and in some length groups. How-

TABLE 1. **Length-Frequency Distribution and Mean Lengths of Largemouth Bass Tagged at Merle Collins Reservoir, 1965–1969**

Length class (fork length-inches)	Number tagged—Year				
	1965*	1966†	1967†	1968	1969
8.0– 8.9	94	2	37	55	17
9.0– 9.9	94	6	3	42	82
10.0–10.9	41	1	9	2	55
11.0–11.9	2	4	5		15
12.0–12.9		9	3		13
13.0–13.9	2	9	7		12
14.0–14.9	9		3		
15.0–15.9	2	1	13		2
16.0–16.9	3		9		3
17.0–17.9		1	6	1	
18.0–18.9		1	3		1
Total	250	34	98	100	200
Mean length	9.6	12.4	12.4	9.1	10.5

* Nonreward tags.
† $1 and $5 reward combined.

TABLE 2. **Numbers of Largemouth Bass Tagged and Tags Recovered at Merle Collins Reservoir, 1965–1971**

Year recovered	Year tagged (number in parentheses)				
	1965* (250)	1966 (34)	1967 (98)	1968 (100)	1969 (200)
1965*	57				
1966	5	7			
1967	1	7	57		
1968	2	3	9	59	
1969	1	2	1	15	127
1970	0	0	1	6	25
1971†	0	0	1	0	13
Total	66	19	69	80	165

* Nonreward tags only.
† Incomplete returns.

TABLE 3. **First-Year Exploitation Rates of Different Sizes of Largemouth Bass at Merle Collins Reservoir, 1965–1969**

(Number Tagged in Parentheses)

Year tagged and recaptured	Fork length in inches						Total	Mean
	8.0–9.9		10.0 11.9		12.0+			
	No. tagged	U_1	No. tagged	U_1	No. tagged	U_1	No. tagged	$\bar{U}_1$
1965*	188	0.34 (64)	46	0.35 (16)	16	0.19 (3)	250	0.33
1966	8	0.13 (1)	5	0.20 (1)	21	0.24 (5)	34	0.21
1967	40	0.70 (28)	14	0.57 (8)	44	0.48 (21)	98	0.58
1968	97	0.61 (59)	2	0.00 (0)	1	0.00 (0)	100	0.59
1969	99	0.63 (62)	70	0.64 (45)	31	0.65 (20)	200	0.64
Total	432		137		113		682	
Mean		0.50		0.52		0.44		0.49

* Nonreward tags only; U_1 adjusted for 0.34 angler nonresponse.

ever, in 1969, when the impact of the strong 1964 year class of slow-growing bass had lessened greatly, fish of each length group were caught at similar rates, indicating that all bass tagged in that year were equally vulnerable. Combining all years also showed only a slight difference in first-year vulnerability of the different sizes of tagged bass.

Weighted estimates of mean annual exploitation rate ($\hat{U}$) for each year of the study increased from 0.36 in 1965 to 0.65 in 1968 and became essentially stable near 0.65 in 1967, 1968, and 1969 (Table 4).

Total annual mortality (a) was consistently high, ranging from 0.71 in 1966 to 0.92 in 1965 (Table 4). The portion of total annual mortality ascribable to annual expectation of death to natural causes (v) decreased from 0.56 in 1965 to 0.11 in 1968.

Mean total instantaneous mortality rate (i) amounted to 1.72, ranging from a high of 2.73 in 1965 to 1.24 in 1966. Instantaneous fishing mortality (p) showed a trend upward from low values for the first 2 years to higher values in the last 3 years. Natural mortality rate (q) declined throughout the study.

TABLE 4. Harvest, Mortality, and Survival Rates of Largemouth Bass at Merle Collins Reservoir, 1965–1969

Year	$\hat{S}$[3]	a	U_1[4]	$\hat{U}$[5]	v	i	p	q
1965[1]	0.08	0.92	0.38	0.36	0.56	2.53	0.99	1.54
1966	0.29	0.71	0.29	0.45	0.26	1.24	0.72	0.52
1967	0.14	0.86	0.60	0.62	0.24	1.97	1.41	0.56
1968	0.24	0.76	0.59	0.65	0.11	1.43	1.22	0.21
1969	0.19[2]	0.86	0.64	0.65	0.21	1.97	1.18	0.49
Mean	0.18	0.82	0.50	0.53	0.27			

[1] Corrected for 0.34 nonresponse.
[2] Based on proportion of 2nd-year returns to 1st year returns only.
[3] Weighted mean survival rate.
[4] U_1 = first-year exploitation rate.
[5] $\hat{U}$ = weighted mean exploitation rate.

DISCUSSION

The annual exploitation rates reported for bass at Merle Collins Reservoir rank higher than those from other waters (Table 5). Results from the first three California lakes listed were obtained using disk dangler tags, while the other tagging studies used jaw tags, which appear to cause high initial harvest due to irritation and interference with feeding (Kimsey 1956). Literature reviews and personal communications resulted in no general consensus about maximum rates at which largemouth bass can be safely harvested. Bennett (1971) stated, however, that largemouth bass cannot be eliminated by sport fishing, but the number of desirable sizes can be drastically reduced.

Data from the creel census coupled with these high harvest rates indicate possible overexploitation. Concurrent with these high harvest rates was a dramatic increase in total annual fishing pressure from 13,007 angler-hours in 1965 to 52,860 in 1970, with a reduced annual catch from 7,682 bass in 1967 to 1,937 in 1970. In addition, data from boat anglers fishing in March, April, and May with lures, minnows, or a combination of both showed declining catches of largemouth bass per hour from 0.33 in 1965 (June only) to 0.13 in 1970. However, the number of hours fished by these anglers remained relatively constant, near 4,000, during the last 3 years, when exploitation rates reached their highest (Table 6). Catch and effort by these anglers most accurately describe the quality of a bass fishery (von Geldern 1972).

Bass, between 8.5 and 11.0 inches FL constituted 64%, 71% and 72% of the total bass harvest during 1968 through 1970, respectively. Age

TABLE 5. Largemouth Bass Annual Survival, Mortality, and Exploitation Rates from Selected Waters.

Water	Survival	Total annual mortality	Exploitation rate	Natural mortality	Source	Comments
Clear Lake, Calif.	0.44	0.56	0.20	0.36	Kimsey 1957	Staple and disk dangler nonreward tags combined; voluntary returns
Sutherland Res., Calif.	0.30	0.70	0.36	0.34	LaFaunce et al. 1964	Spaghetti and disk dangler nonreward tags. Recovered in total creel census.
Folsom Lake, Calif.	0.11	0.89	0.40	0.49	Rawstron 1967	Disk dangler $5 reward tags
Merle Collins Res., Calif.						
1965	0.08	0.92	0.36	0.56		Disk dangler nonreward tags corrected for 0.34 non-response
1966	0.29	0.71	0.45	0.26		
1967	0.14	0.86	0.62	0.24	Present study	Disk dangler $5 reward tags
1968	0.24	0.76	0.65	0.11		
1969	0.19	0.86	0.65	0.21		
Millerton Lake, Calif.	----	----	0.20	----	Fisher 1953	Jaw tags; voluntary returns
Ridge Lake, Ill.	0.65–0.60	0.35–0.40	0.25–0.30	0.05–0.11	Bennett 1954	Pond draining and creel census; marked fish
Sugarloaf Lake, Mich.	0.30	0.70	0.26	0.44	Cooper and Latta 1954	Population estimate with marked fish and complete creel census
Gladstone Lake, Minn.	----	0.609	0.136	0.473	Maloney et al. 1962	Schumacher-Eschmeyer population estimate and creel census
Watauga Res., Tenn.	----	----	0.416	----	Chance 1955	Total harvest not annual, strap jaw tags voluntary returns; high publicity; lakes recently opened to fishing. Author felt fish were overtaxing food supply and were unusually susceptible to angling.
South Holston Res., Tenn.	----	----	0.412	----	Chance 1955	
Norris Res., Tenn.	----	----	0.184	----	Manges 1950	Jaw strap tags; voluntary returns
Norris Res., Tenn.	----	----	0.185	----	Eschmeyer 1942	April–Nov. only; jaw strap tags
Shoe Lake, Ind.	----	----	0.20	----	Ricker 1942	Population estimate mark and recapture and creel census

determinations indicated that these fish were primarily 1 and 2 years old.

Mean annual weight of individual bass increased dramatically during the latter years, while the annual catch declined steadily (Table 6). Bass averaged 1.01 lb. in 1970. However, fewer small bass (less than 0.5 lb.) have been seen in the census, while the number of extremely large bass (5–8 lb.) recorded has increased. Commercial fisheries which have been studied extensively typically show an almost immediate increase in individual growth rate and recruitment following increased fishing pressure (Ricker 1963) or after permissive changes in regulations (Beverton and Holt 1957). This effect, however, is short-lived and its application to a sport fishery may be tenuous.

TABLE 6. **Catch Statistics for Largemouth Bass at Merle Collins Reservoir, 1965–1970**

Year	1965	1966	1967	1968	1969	1970
Total anglers	3,110	5,118	8,191	10,118	11,756	11,170
Total angler hours	13,007	17,376	27,801	35,930	48,222	52,860
Annual catch	3,447	5,407	7,682	3,582	2,300	1,937
Total weight	1,208	1,401	2,931	1,932	1,937	1,959
Mean annual weight	0.28	0.20	0.38	0.54	0.84	1.01
Catch per hour (all anglers)	0.27	0.31	0.28	0.10	0.05	0.04
Catch—March, April, May; Boat; Lures, Minnows, combination of lures and minnows	428*	2,365	2,791	1,085	663	493
Hours (as above)	556*	4,922	5,326	3,707	4,288	3,933
Catch/hour (as above)	0.77*	0.48	0.52	0.29	0.15	0.13

* Includes June data only. Lake not open March, April, May.

Older reservoirs in northern California have evidenced declining catches. In 1962, anglers at Folsom Lake had a catch/hour for largemouth bass of 0.14, but this declined to 0.04 in 1969 (von Geldern 1972). He postulates, as does Murphy (1966), that this decline may be due to differential exploitation of bass and bluegill where anglers select largemouth bass at only a slightly different rate than bluegill (*Lepomis macrochirus*), but this difference has caused dramatic shifts in the populations of both species there since bluegills spawn over a long period and at a smaller size. At Merle Collins Reservoir, bluegill were originally scarce in angler and in net catches. Large fish (6–10 inches) made up the bulk of the catch (Hashagen MS). Now bluegills of all sizes are more abundant in angler catches than largemouth bass. Their mean size has also been dramatically reduced. This unbalanced situation has been noted by many workers and this shift has generally worked to the detriment of bass populations (Bennett 1971). Heavy exploitation for several years (partial chemical treatment) of largemouth bass dramatically reduced bass populations and allowed nearly complete dominance of bluegill in ensuing years (Cooper et al. 1963).

Shasta Lake was considered an excellent largemouth bass producer (Chester A. Woodhull, pers. comm.) until recently, when catches of largemouth bass became dramatically reduced. Smallmouth bass now outrank largemouth there by 20 to 1 in anglers' catches (Weidlein 1971). At Norris Lake, Tennessee, largemouth bass constituted approxi-

mately 40% of the total catch of bass from 1938 through 1944 and showed a consistent downward trend, finally reaching only 4% in 1953 (Chance 1958). Concurrently the percentage of smallmouth bass, while highly variable in the early years, equalled or exceeded the percentage of largemouth bass in the later years (ibid.). At Merle Collins Reservoir, smallmouth bass made up from 5.7 to 11.4% of the total bass catch for the first 4 years, but in 1969 and 1970 the contribution of smallmouth rose dramatically to 29.7 and 35.2%, respectively. Since the smallmouth bass spawns earlier and their young grow faster than the largemouth bass during the first year at Merle Collins Reservoir (Hashagen MS), we postulate that competition between the two basses may be sufficient to reduce recruitment of largemouth bass. No estimates of the exploitation rate of smallmouth bass at Merle Collins are available, but 1- and 2-year-old fish make up 90% of the catch, indicating low survival to older age classes and probably high exploitation rates.

The establishment in 1967 of an abundant threadfin shad (*Dorosoma petenense*) population may also have contributed to lower recruitment of largemouth bass in later years. At Lake Nacimiento, California, an inverse relationship existed between the abundance of adult threadfin shad and young-of-the-year largemouth bass (von Geldern 1971).

An exceptionally high return of spotted bass (*Micropterus punctulatus*) provided further evidence of heavy exploitation rates of black basses at Merle Collins. Seventy fish were tagged with $5 reward tags and introduced in September 1970. Anglers harvested 72% of these tagged bass in the first year.

In summary, the combination of the highest reported exploitation rates, decreasing annual landings, decreasing catch/hour for proficient bass anglers, increased total fishing pressure, possible lowered recruitment, differential harvesting of bluegill with an attendant increase in their abundance in the catch, and possible competition with smallmouth bass and threadfin shad lead us to conclude that largemouth bass and other black basses may be now at or near maximum exploitation. Any further increases in harvest rates, fishing pressure, and bluegill, smallmouth bass, and adult threadfin shad populations or loss of successive year classes would cause even further declines in the largemouth bass fishery at Merle Collins Reservoir.

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WINTER FOOD OF TROUT IN THREE HIGH ELEVATION SIERRA NEVADA LAKES[1]

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A year-round analysis of trout stomach contents from three high elevation Sierra Nevada lakes showed that brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo gairdneri*) fed on a variety of aquatic prey throughout the winter. However, under-ice feeding was poor relative to summer feeding even when the loss of surface forms is accounted for. Since fish were active and readily caught with bait at temperatures of 1 C, we believe that poor feeding was due to reduced availability of important aquatic prey species rather than to a change in trout activity or readiness to feed.

INTRODUCTION

Even though trout in high elevation Sierra Nevada lakes spend over half their lives under ice, little is known of their food habits under these conditions. Swift (1970) found that rainbow trout and brook trout in Castle Lake fed entirely on benthic prey in the winter, but he gave no details. Similarly, Berglund (1968) found that brown trout (*Salmo trutta*) in a Swedish pond fed well under ice, but the situation he described was different than that considered here, as discussed later in this paper. In this study, we analyzed stomach contents of trout in three alpine lakes for a full year (December 1969 through November 1970) to determine how feeding under ice cover differs from feeding during ice-free conditions. No attempt was made to compare the feeding habits of the two species studied since they were not found in the same lakes, and the lakes varied considerably in their physical and faunal characteristics.

STUDY AREAS

The three lakes studied are all on the eastern slope of the Sierra Nevada, in Inyo and Mono counties, California. Lower Gem Lake (lat 37° 24′ N, long 118° 45′ W) is in the Rock Creek drainage in Inyo County at an elevation of 10,850 ft. It is 1.5 acres in surface area and its maximum depth is 6 ft. "Chickenfoot Pothole" (which has no official name) is 0.7 mile downstream in the same drainage at an elevation of 10,750 ft. Its surface area is 1.0 acre and its maximum depth is 7 ft. Both Lower Gem Lake and Chickenfoot Pothole are densely populated with naturally spawned brook trout, but a few rainbow and golden trout (*Salmo aguabonita*) are also present. Our study concentrated on brook trout; those caught ranged from 93 to 177 mm SL.

Dunderberg Lake (lat 38° 5′ N, long 119° 15′ W) is located at 10,350 ft near the headwaters of the East Walker River in Mono County. It has a maximum surface area of 3.5 acres and a maximum depth of 12

[1] Accepted for publication January 1972.

ft. The small inlet stream flows only during spring runoff, and there is no surface outlet. During the winter the water level drops 3 to 4 ft, exposing the peripheral shelf and reducing the surface area by as much as 60%. The only fish present are Kamloops strain rainbow trout. They were planted by the California Department of Fish and Game as fingerlings in August 1968 (171 oz at 41.2/oz). The fish taken ranged from 73 to 120 mm SL and averaged 10.8 g during the year of this study.

METHODS AND MATERIALS

Twelve monthly samples of 10 fish were taken by angling from each of the three lakes. Lower Gem Lake and Chickenfoot Pothole were sampled near the first of the month and Dunderberg Lake near the middle of the month. All samples were taken after mid-day to allow for morning feeding.

Fish were weighed and measured and their stomachs were preserved in 70% ethanol. Stomach contents were examined under a binocular microscope and counted by major taxonomic group. We also categorized organisms as to how they became available to trout: "aquatic" forms included zooplankters and invertebrates of benthic origin, while "surface" forms included all terrestrial arthropods and winged stages of aquatic forms.

Volumes were estimated by centrifugation. The stomach contents of each fish were placed in a Wintrobe tube and spun at 2,500 rpm for 5 min. The contents were then packed with a rod, spun to constant displacement, and the resulting volume was read to the nearest 0.004 ml in a graduated rack.

RESULTS

Surface food was, of course, absent during the 6- to 7-month period of complete ice cover, but trout fed on aquatic organisms. Chironomid larvae, zooplankters (copepods and cladocerans), and bivalve mollusks made up most of the diet of trout during this period (Table 1). When the lakes were free of ice, trout still fed on chironomid larvae, zooplankters, and mollusks, but they also consumed significant numbers of chironomid pupae and adults, as well as terrestrial hemipterans. A few other forms were taken at various times of the year, but together they amounted to less than 5% (by number) of the diet of trout.

Total food consumption was generally greater during ice-free months due to increased consumption of aquatic forms as well as utilization of surface food (Figure 1, Table 1). In Dunderberg Lake, for example, the highest summer stomach content volume for 10 fish was 58 times the lowest winter volume. The summer increase in aquatic forms was largely composed of chironomid pupae, but fish also took more chironomid larvae and zooplankters in summer than in winter. Surface feeding began as soon as the ice cleared and increased to a maximum in September or October.

Trout were observed to be quite active beneath the ice, even at temperatures of 1 C. It was not uncommon for four or five fish to converge on bait as it was lowered under the ice. The average time to catch 10 fish was 76 min when the lakes were free of ice, but only 43 min during the period of ice cover.

TABLE 1. **Monthly Breakdown of Feeding Habits in the Three Lakes Studied, December 1969 Through November 1970. Values Indicate the Number of Organisms in Each Taxonomic Category Taken by 10 Fish. The Source of Food Items (Aquatic or Surface, see Text) Is Also Indicated for Each Lake.**

	Lower Gem Lake—Brook trout											
	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Aquatic												
Diptera[1]—larvae	126	35	33	30	430	688	911	2,633	2,364	311	94	428
—pupae	21	1	--	--	1	319	2,135	606	841	1,010	679	124
Ephemeroptera—nymph	2	4	3	7	25	5	29	1	--	--	99	68
Plecoptera—nymph	2	5	2	5	1	--	13	--	--	--	3	18
Trichoptera—larvae	15	--	--	--	11	5	1	1	--	29	5	105
Coleoptera—larvae	2	--	--	--	--	1	5	--	--	--	1	8
Hydrachnida	--	1	1	--	--	--	1	--	--	--	5	3
Mollusca	6	6	4	8	11	209	44	98	47	18	6	7
Ostracoda	--	--	--	--	--	--	--	--	--	6	428	--
Zooplankton[2]	--	2	1,518	843	587	133	3	90	--	26	336	131
Miscellaneous[3]	--	--	4	--	--	--	1	2	1	2	4	1
Surface												
Diptera—adult	--	--	--	--	--	--	5	9	243	305	887	36
Hymenoptera—adult	--	--	--	--	--	--	1	--	8	10	3	--
Coleoptera—adult	--	--	--	--	--	--	4	--	2	--	4	1
Hemiptera—adult	--	--	--	--	--	--	31	12	15	11	599	10
Miscellaneous[3]	--	--	--	--	--	--	5	2	--	--	5	--

TABLE 1. (Continued)

	Chickenfoot Pothole—Brook trout											
	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Aquatic												
Diptera[1]—larvae	211	231	249	312	991	997	665	156	414	409	79	260
—pupae	10	--	2	--	1	--	605	718	48	219	20	74
Ephemeroptera—nymph	--	--	--	--	--	--	41	8	2	8	2	16
Plecoptera—nymph	1	--	--	--	--	--	4	1	--	--	--	4
Trichoptera—larvae	8	1	--	--	--	18	1	1	--	2	7	21
Coleoptera—larvae	--	--	1	--	1	2	25	1	--	3	3	9
Hydrachnida	56	14	--	2	1	28	8	3	16	7	64	2
Mollusca	11	12	17	23	187	36	119	5	34	12	9	21
Ostracoda	--	--	--	--	--	--	--	--	2	8	--	1
Zooplankton[2]	50	71	--	--	5	3	1	--	573	3,295	57	1,049
Miscellaneous[4]	--	--	--	--	--	--	6	2	13	2	1	1
Surface												
Diptera—adult	--	--	--	--	--	--	51	53	7	350	129	51
Hymenoptera—adult	--	--	--	--	--	--	11	3	15	6	7	3
Coleoptera—adult	--	--	--	--	--	--	6	4	--	--	8	9
Hemiptera—adult	--	--	--	--	--	--	75	32	6	6	361	52
Miscellaneous[1]	--	--	--	--	--	--	19	3	2	8	10	4

TABLE 1. (Continued)

	Dunderberg Lake—Rainbow trout											
	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Aquatic												
Diptera[1]—larvae	33	7	1	102	6	93	15	17	50	241	1,778	112
—pupae	1	--	1	3	3	--	304	2	331	2,189	111	21
Coleoptera—larvae	--	--	--	--	--	--	--	15	9	--	--	--
Hydrachnida	--	--	--	--	--	2	114	--	1	--	--	--
Mollusca	1	--	--	27	--	--	--	--	--	--	--	--
Zooplankton[2]	26	304	35	57	103	--	10	72	--	165	--	253
Miscellaneous[3]	--	1	1	--	--	--	13	9	39	2	4	2
Surface												
Diptera—adult	--	--	--	--	--	--	20	78	1,046	8,615	108	--
Hymenoptera—adult	--	--	--	--	--	--	2	2	161	5	23	--
Coleoptera—adult	--	--	--	--	--	--	13	2	66	--	24	--
Hemiptera—adult	--	--	--	--	--	--	1	133	183	52	392	--
Miscellaneous[4]	--	--	--	--	--	--	1	4	4	2	--	--

[1] Nearly all of the family Chironomidae.
[2] Zooplankton consisted of copepods and cladocerans.
[3] Miscellaneous consisted of: Coleoptera adults, Hemiptera adults and Annelida (aquatic); Trichoptera adults and Arachnida (surface).
[4] Miscellaneous consisted of: Coleoptera adults, Hemiptera adults and Annelida (aquatic); Ephemeroptera adults, Plecoptera adults, Trichoptera adults, Lepidoptera larvae and Arachnida (surface).
[5] Miscellaneous consisted of: Coleoptera adults, Hemiptera adults and Collembola (aquatic); Trichoptera adults, Orthoptera adults, Raphidiodea adults and Arachnica (surface).

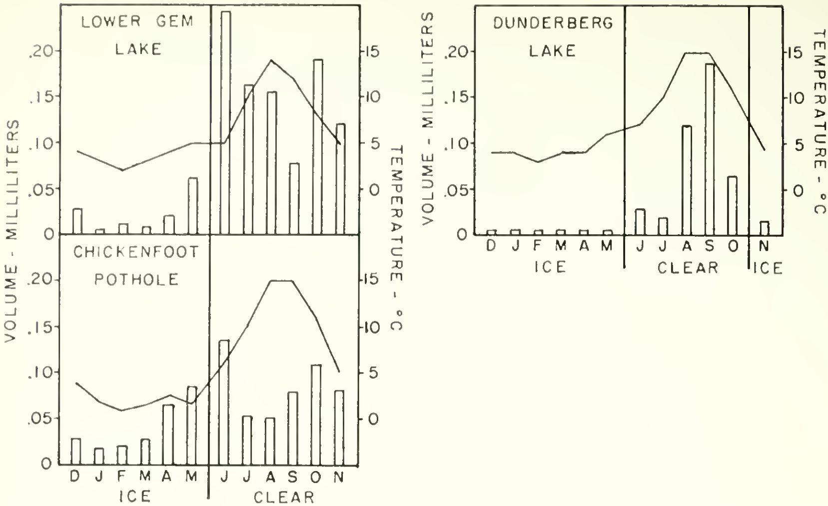

FIGURE 1. Mean monthly stomach content volumes (bars) and maximum water temperatures (lines) from three study lakes. Maximum temperatures occurred at lake bottom during periods of ice cover and on the surface during ice-free periods.

DISCUSSION

Our results showed that both species of trout fed throughout the winter, and that during the period of ice cover they consumed only animals of aquatic origin. This agrees with the findings of Swift (1970) in Castle Lake.

The variety of aquatic types consumed was almost as great under ice as during ice free conditions, but the numbers of prey taken were considerably less in the winter. In his study of brown trout in a Swedish pond, Berglund (1968) found the opposite result. The trout fed most and grew fastest in winter and early spring, despite ice cover and temperatures below 4 C. Some larger fish even lost weight in the summer. Berglund found that the rate of feeding and growth were very closely related to abundance of *Asellus*, the primary prey of trout in the pond, and *Asellus* happened to be most abundant when the pond was ice covered. Assuming that rainbow and brook trout are affected as much by prey availability as are brown trout, and as little affected by cold water and ice cover, we can conclude that the poor feeding observed was due primarily to low availability of the forms utilized. The enthusiasm with which trout in our study took bait (and even bare hooks) in temperatures as low as 1 C and under ice and snow as thick as 5 ft seems to support this assumption.

Since differences in prey availability best explain seasonal changes in feeding success, we should comment on possible reasons for these differences. Some important prey types (e.g. chironomid larvae) must have decreased in number during the winter through natural mortality and predation since they do not reproduce during this period. However,

the fact that such forms were less utilized early in the period of ice cover than later suggests that availability may be as much affected by prey size or behavior as by abundance *per se*.

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NOTES

REPRODUCTIVE FAILURE OF PELAGIC CORMORANT, SAN LUIS OBISPO COUNTY, CALIFORNIA, 1970

Coastal rocks and headlands in San Luis Obispo County have long provided nesting sites for pelagic cormorants (*Phalacrocorax pelagicus*), pigeon guillemote (*Cepphus columba*), western gulls (*Larus occidentalus*), and black oystercatchers (*Haematopus bachmani*).

In 1969, the author conducted a nest survey along a 1.3 mile strip of coastline below Montana de Oro State Park. The transect on the Pecho Ranch extended south from Coon Creek to the property line. Permission was extended by Mr. O. C. Field to walk out the transect periodically and record nesting activity. Pelagic cormorant reproductive failure was first observed in 1969 when only 3 young were hatched. However, inadequate field notes provided no quantitative assessment of this reproductive failure.

In the 1970 survey, attention was directed towards documenting the number of nesting birds, eggs produced, and number of young successfully fledged. Observations commenced on March 22 with the first nest building activity on April 4. Egg laying commenced on April 18 and eggs were last seen on August 8. From the period March 22 to August 8, 12 days were spent recording observations. Thirty nesting pairs of pelagic cormorants produced 66 eggs from which only 2 young were hatched. These two birds disappeared soon after hatching. The fate of 3 eggs was undetermined. Nine pairs of nesting cormorants failed to produce any eggs.

—*Leonard B. Penhale, Department of Parks and Recreation. Accepted for publication January 1972.*

THE REOCCURRENCE OF THE CALIFORNIA SCORPIONFISH, *SCORPAENA GUTTATA* GIRARD, IN MONTEREY BAY

On October 19, 1970, a California scorpionfish was taken in a trawl fished at 25 fathoms, approximately 3 nautical miles off Point Santa Cruz, Santa Cruz, California (lat 36°54'N, long 122°02'W), by the drag boat *Saturnia*. Recent literature (Phillips, 1957; Miller, Gotshall and Nitsos, 1965; Eschmeyer and Baily, 1970) has established the range of *S. guttata* as being from Point Abreojos, Baja California to Point Arguello, California. However, Roedel (1953) reported a record of *S. guttata* in the 1850's as far north as Monterey Bay. This record was the original description for this species made by Girard (1854). Therefore, this latest capture of *S. guttata* constitutes a reoccurrence of the species in the type locality of Monterey Bay after over 116 years.

The specimen, a 212 mm (SL) male, that had a fresh weight of 326 g, is deposited in the ichthyology collection of the Moss Landing Marine Laboratories (accession number M-12).

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—*Daniel H. Varoujean, Moss Landing Marine Laboratories, Moss Landing, California 95039. Contribution from the Moss Landing Marine Laboratories, number 21.* *Accepted March 1972.*

SYMBIOSIS IN THE BLACKTAIL SNAILFISH, *CAREPROCTUS MELANURUS*, AND THE BOX CRAB, *LOPHOLITHODES FORAMINATUS*

On October 14, 1970 while on a bottomfish, longline cruise in Monterey Bay with the *RV Nautilus* a box crab, *Lopholithodes foraminatus*, was taken in 53–55 fathoms at lat 36° 42.5′N, long 121° 56.5′W. The crab was placed in a covered plastic container along with the fishes taken on the longline. While working up the fishes, approximately $2\frac{1}{2}$ hr later, the live crab was placed in a pail of sea water. Immediately the crab spread its appendages and large numbers of larval blacktail liparids, *Careproctus melanurus*, emerged from the underside of the crab. Most of the liparids were alive and swam actively. Several of the liparids were preserved and the remainder were left overnight in a tub of sea water with the crab to see if they would re-enter the crab. All of the animals were dead the following morning probably due to the inadequate holding facility. Later examination yielded 212 *C. melanurus* larvae (9–12mm) and three eggs, two of which were nearly ready to hatch (Figure 1).

The following day another *L. foraminatus* was taken in 76–82 fathoms (lat 36° 44′N, long 121° 58′W). It was kept out of the water for approximately 1 hr. Upon being placed in sea water live *C. melanurus* started emerging past the mouth parts of the crab. The crab was immediately removed from the water and frozen. When the carapace was later removed from this crab *C. melanurus* were found in the gill filaments.

—*Richard H. Parrish, Marine Resources Region, California Department of Fish and Game.* *Accepted for publication March 1972.*

FIGURE 1. Larvae and eggs of the blacktail snailfish.

A NEW RANGE RECORD FOR THE UMBRELLA CRAB, *CRYPTOLITHODES SITCHENSIS* BRANDT

Biologist-divers conducting subtidal ecological investigations have recently discovered the umbrella crab *Cryptolithodes sitchensis* Brandt (Figures 1 and 2), south of its recorded range, Sitka, Alaska to Pacific Grove, California (Schmitt, 1921). The umbrella crab is unusual in that the carapace totally shields the appendages.

Three specimens have been collected alive from the inshore waters near San Diego, California. The first two specimens were collected by R. H. McPeak, one on March 20, 1971, the second one April 25, 1971 (Table 1). The first specimen was found off La Jolla, California at a depth of approximately 12 m (40 ft). The second specimen was collected off Point Loma, California at a depth of approximately 17 m (55 ft). A third specimen was collected by D. W. Gotshall of the California Department of Fish and Game, on June 8, 1971. The specimen was also collected off Point Loma, California, but at a depth of approximately 6 m (20 ft). The third specimen was the first brought to the attention of the author, who subsequently located the other specimens in the private collection of Mr. McPeak. All three specimens fall into the size range cited by Schmitt (1921).

These records constitute a range extension of approximately 330 miles, from Pacific Grove to Pt. Loma, California.

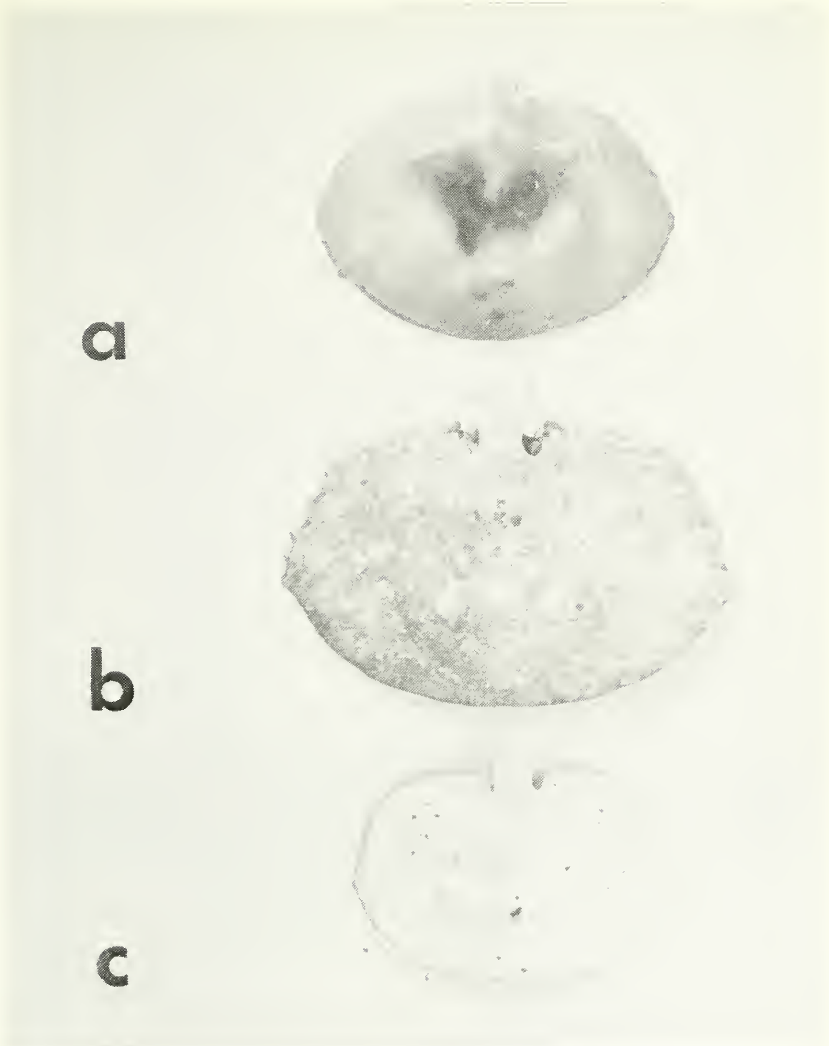

FIGURE 1. *Cryptolithodes sitchensis* Brandt, dorsal view of three specimens collected near San Diego, California (Table 1). (Grid = 0.1 inch).

ACKNOWLEDGMENT

I wish to thank both D. W. Gotshall and R. H. McPeak for making the specimens available to me, and Dr. J. Garth and Miss Janet Haig for assisting in locating the first two specimens.

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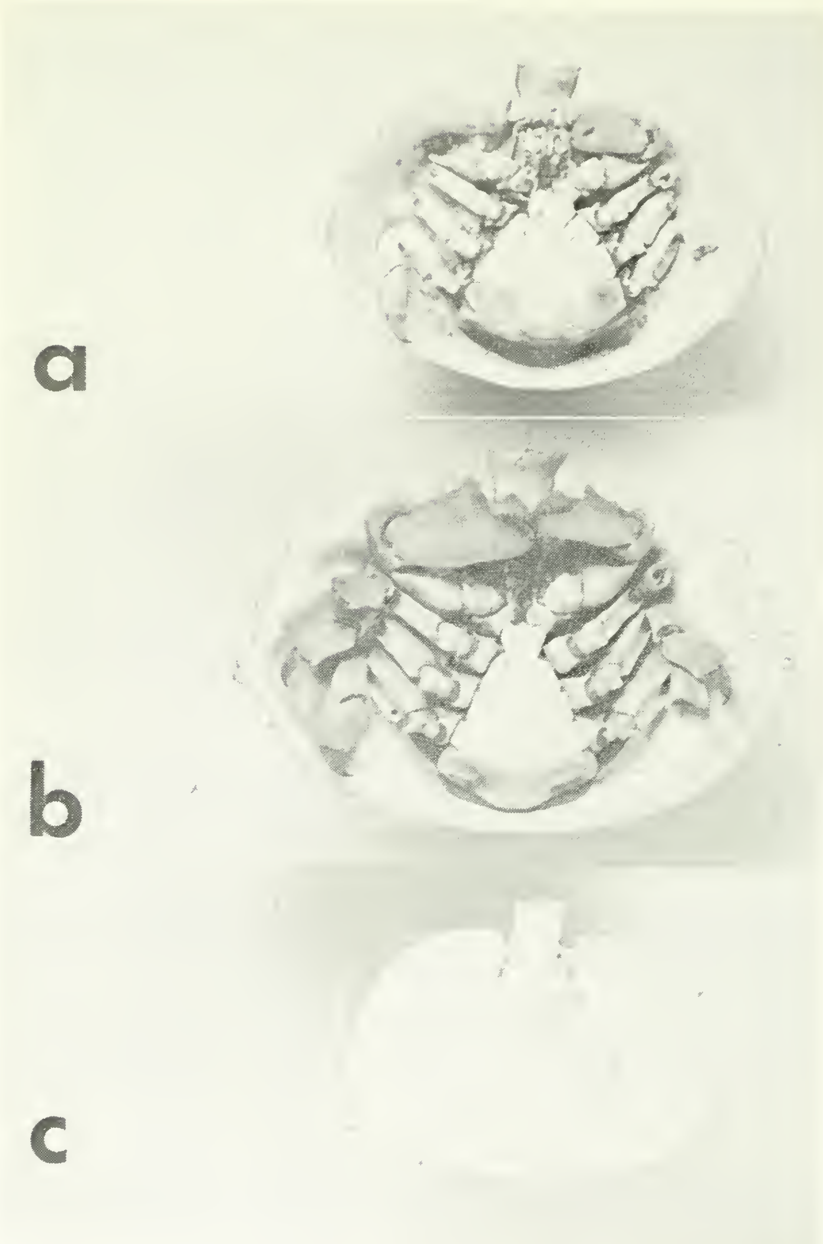

FIGURE 2. *Cryptolithodes sitchensis* Brandt, ventral view of three specimens collected near San Diego, California (Table 1). (Grid = 0.1 inch).

TABLE 1. **Collection Data for *Cryptolithodes sitchensis* Brandt, Collected Near San Diego, California**

	Date	Locality	Depth	Carapace length	Carapace width
Specimen (a)	March 20, 1971	Point Loma, ½ mile offshore from tip of point. Under a rock	40 ft.	33.1 mm	43.9 mm
Specimen (b)	April 25, 1971	La Jolla, ¾ mile offshore from Wind 'n Sea Beach. Under red abalone shell	55 ft.	39.0 mm	55.4 mm
Specimen (c)	June 8, 1971	Point Loma, ¼ mile offshore from tip of point. On coarse sand	20 ft.	28.0 mm	39.2 mm

FIRST RECORD OF A REVERSED BUTTER SOLE, *ISOPSETTA ISOLEPIS*

Most flatfish species tend to be monomorphically dextral (right eyed) or sinistral (left eyed). Occasionally the pigmentation and eyes of a flatfish are formed on the side on which they do not normally occur, a condition referred to as reversal. In reversal, all asymmetrical structures such as jaws, dentition and scalation, along with fin ray measurements and counts are transposed. A reversed flatfish is thus externally the mirror image of its normal counterpart. Gudger (1935) and Hubbs and Hubbs (1945) have given extensive accounts of the phenomenon of reversal in flatfishes.

Internally, reversed flatfishes are rarely mirror images of normal individuals. Most fishes, whether symmetrical or asymmetrical, have a monomorphic liver-intestine relationship in which the liver is positioned on the left side of the body cavity and the intestinal coils are on the right. In pleuronectids the optic chiasma is generally monomorphic with the nerve from the right optic lobe (to the left eye) crossing dorsally to the left optic nerve (Parker, 1903).

Neither of these internal relationships seem to be associated with reversal nor interrelated as normal flatfishes have been found with one or the other abnormal internal conditions (Haaker and Lane, in preparation). Only one individual, a pleuronectid, *Tanakius kitaharae*, has been found exhibiting complete external and internal reversal (Hubbs and Hubbs, 1945).

On November 4, 1971, Nancy Nelson, Marine Biologist at the Eureka Laboratory of the California Department of Fish and Game, found a reversed butter sole, *Isopsetta isolepis*, Pleuronectidae, (Figure 1) in a trawl catch made off the Klamath River in 35 fathoms of water (lat

FIGURE 1. Eyed side of the reversed butter sole from off the Klamath River, California.

41° 32.3′ N, long 124° 17.0′ W). She passed the fish on to John Fitch, who subsequently gave it to me. This fish is the first record of any anomalous condition occurring in *I. isolepis*, although Barnhart (1936) includes, without comment, a line drawing of a sinistral individual.

The specimen is a male, 178 mm SL. Fin ray counts fall within the range listed by Clemens and Wilby (1961), and are as follows: dorsal, 88; anal, 65; eyed side (left) pectoral, 13; blind side pectoral, 12; and pelvics, 6. External reversal is complete including pigmentation, scalation, jaws and eyes. The liver-intestine relationship was reversed. The optic decussation follows the normal monmorphic pattern for pleuronectids. The specimen has been deposited in the California Academy of Sciences icthyological collection as CAS 27155.

The cause of external reversal is probably due to genetic or polygenic factors. The rarity of this anomaly may indicate a mutational cause. Reversed liver-intestinal relationships are contrary to the general teleost condition and may also be due to mutation.

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—*Peter L. Haaker, Marine Resources Region, California Department of Fish and Game,* *Accepted March 1972.*

THE COTTONMOUTH JACK, *URASPIS SECUNDA*, ADDED TO THE MARINE FAUNA OF CALIFORNIA

During late September 1971, a fisherman on the party boat *Frontier* caught an adult cottonmouth jack, *Uraspis secunda* (Poey), in the vicinity of the Palisades on the offshore side of Santa Catalina Island, California. This fish, 323 mm SL, 405 mm TL, and weighing 930 g, was saved and turned over to the Department of Fish and Game by Art Gronsky of Art's Landing, Balboa Pavillion.

Berry (1965) noted that "this is a very unusual and rare species, and is found primarily in offshore waters and around oceanic islands in tropical and subtropical waters around the world." He reported that fewer than 200 individuals are known to have been taken throughout the world oceans, and that in the eastern Pacific, *U. secunda* was known only from the vicinity of the Revillagigedo Islands. A juvenile captured off Costa Rica (Hunter and Mitchell, 1966) was the first record of the species from inshore areas in the eastern Pacific and represented a southern range extension from the Revillagigedos of about 1,500 straightline miles. The adult captured at Santa Catalina Island appears to be only the second record for *U. secunda* from inshore areas and represents a northward extension of the range of some

FIGURE 1. Cottonmouth jack, *Uraspis secunda*, 323 mm SL from Santa Catalina Island, California. *Photograph by Jack W. Schott.*

900 miles. This specimen has been placed in the collections of the Natural History Museum of Los Angeles County (LACM 32108-1).

Meristics on this fish are: D. V-I, 28; A. II-I, 22; P. I, 22; P_2. I, 5; rakers on first gill arch 6 + 16 = 22; posterior rakers on first gill arch 3 + 12 = 15; pored scales on lateral line 53 + 33 keeled scutes = 86. A photograph taken with a polaroid camera at the time of its capture shows a color pattern identical to that described by Hunter and Mitchell (1966) for the juvenile netted off Costa Rica.

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—*John E. Fitch, California State Fisheries Laboratory, Department of Fish and Game, 350 Golden Shore, Long Beach 90802.* *Accepted for publication February 1972.*

A CASE FOR STRIPED MULLET, *MUGIL CEPHALUS*, SPAWNING AT SEA

Although current literature suggests that striped mullet are catadromous, conflicting reports on their reproductive history are common. There is general agreement that spawning occurs during five winter months (October through February) with peak activity primarily during December and January, but evidence as to where they spawn (e.g., freshwater, tidal creeks and estuaries, nearshore shallows, or well offshore over deep water) is almost entirely circumstantial.

Breder (1940) reported observing what he thought was spawning behavior in a small tidal creek on the Florida west coast during Feb-

ruary. Based upon the behavior he described, his assumption that spawning was taking place is logical, but the lack of factual evidence in the form of observed or recovered eggs, or finding residual eggs in the ovaries of some of the females he captured, casts doubt on his hypothesis.

Arnold and Thompson (1958) presented extremely convincing evidence that they observed the actual spawning of striped mullet in the Gulf of Mexico in an area 40 to 50 miles southeast of the Mississippi River Delta during December 1956. Not only did they observe behavior similar to that described by Breder (1940), they dipnetted females from which eggs could be extruded with the slightest abdominal pressure, and milt ran freely from the captured males. As a clincher, plankton tows in the vicinity yielded several hundred fertilized eggs and over 2,000 larvae of *Mugil cephalus.*

Hendricks (1961) recorded gonad condition in Salton Sea mullet throughout the year, and noted that the female gonad cycle peaked in December and January, but at no time did he find females with completely developed eggs which were free in the ovary. Based upon this negative information, plus behavioral observations and the absence of mullet eggs in plankton tows, he concluded that mullet did not spawn in Salton Sea.

Johnson and McClendon (1970) on the other hand, presented a fairly convincing set of circumstances for *Mugil cephalus* spawning in fresh water. During March 1966, they captured 31 postlarval mullet some 120 miles upstream from the mouth of the Colorado River. By using growth data of Anderson (1958), they demonstrated that these fish could not have hatched in saline waters and then have arrived at Morales Dam while only 28 to 40 mm SL.

In view of such conflicting reports, which for the most part are circumstantial, the capture of a fully mature female *Mugil cephalus* some 40 miles southwest of Cape Colnett, Baja California, during late September 1971 has supplied additional fuel for the advocates of striped mullet spawning on the high seas. This fish, 395 mm SL, 485 mm TL, and weighing 1,400 g was brailed aboard the purse seiner *Beverly Lynn* with 18 tons of bluefin tuna, *Thunnus thynnus*, at lat 30°28'N, long 116°51'W where the charted depth is 900 fathoms. When firm pressure was applied to the abdomen of this fish, fully developed eggs were extruded from the vent. An examination of the tremendously enlarged ovaries revealed numerous loose eggs in the lumen. George Fukuzaki, skipper of the *Beverly Lynn*, reported that they did not see any other mullet in the area, nor could he recall ever having seen adult mullet much beyond the surf zone around the entrance to bays and lagoons prior to this instance. This specimen has been placed in the fish collection of the Natural History Museum of Los Angeles County (LACM 32111-1).

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—*John E. Fitch, California State Fisheries Laboratory, Department of Fish and Game, 350 Golden Shore, Long Beach 90802. Accepted for publication February 1972.*

A RANGE EXTENSION FOR THE LOGPERCH

On December 20, 1971, an adult logperch, *Percina caprodes* (Rafinesque), was taken on the Mendota Wildlife Area. The fish, measuring 76 mm TL, was seined from a drainage canal at a point ½ mile east of Fresno Slough by David Allen of the Department of Fish and Game and myself. This represents a southern range extension of the logperch in California.

A native of the eastern United States, logperch were accidentally introduced into California by the U. S. Fish and Wildlife Service in 1953. The fish were planted at Beale Air Force Base in three lakes located on Hutchinson Creek, a tributary of Dry Creek, which is a tributary to the Yuba River. In 1958, breeding populations were present in two of the lakes (McKechnie 1966). Logperch have apparently spread down the Yuba and Sacramento rivers to the Sacramento-San Joaquin Delta. From there they have made their way down the Delta-Mendota Canal which empties into Fresno Slough. Logperch have also been reported from the California Aqueduct near Tracy in the spring of 1970 (P. Hansen, pers. comm.).

Logperch prefer slow moving stream conditions and shallow lake environments (Trautman 1957), both of which are abundant in the Sacramento and San Joaquin River drainages. This record indicates that logperch are in the process of becoming established in suitable waters thoughout the Central Valley.

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—*David G. Farley, Dep. of Biology, Fresno State College, Fresno, Calif. 93710. Accepted January 1972.*

BOOK REVIEWS

Biology and Water Pollution Control

By C. E. Warren, W. B. Saunders Co., Philadelphia, Pa., 1971; xvi + 434 p., illustrated. $11.00.

Water pollution biologists, like other biologists, have usually concentrated their individual efforts on one or another of the levels of biological organization. Biological systems can be categorized into four levels: morphology and physiology, ecology of the individual organism, population ecology, and community ecology. Dr. Warren's book is logically separated into these four parts, with elaboration on appropriate studies of each level of biological organization. The book is packed with information and presents a delightful review for the working biologist. Nonbiologists, however, may have difficulty absorbing the details of the biology presented in this book.

Dr. Warren begins by tracing the history of water pollution in North America and the study of its biological consequences. Standards and criteria are defined, and water chemistry and physics are discussed in the first chapters. These sections are followed by discussions of morphology, genetics and physiology, and how they relate to environmental change. Autecology, bioenergetics, behavior, population, and community ecology are tied in with pollution and the effects of environmental change on survival and production. The last chapters cover biological indices, waste treatment, the acceptability and evaluation of ecological change, and the roles of water pollution biologists. It is these chapters which concentrate on water pollution.

Because the text is almost biologically all-embracing, I highly recommend it for both the generalist and specialist, the aquatic or fishery biologist and the pollution biologist, respectively.—*James W. Burns*

Sea Shells of Tropical West America; Marine Mollusks from Baja California to Peru—Second Edition.

By A. Myra Keen; Stanford University Press, Stanford, Cal., 1971; 22 color plates, profusely illustrated with black and white text figures, XIV + 1064 p., $29.50.

This revision differs in so many ways from the first edition that it rightfully could be considered a "new" publication. It covers a larger geographical area, includes groups not previously treated, has a chapter on rejected and indeterminate species, plus a section entitled "geographic aids," and 13 new species are described.

The bulk of the text is occupied with systematic treatment of more than 3,300 species of mollusks. Within each of the seven classes of mollusks, the arrangement for all levels above species is more or less conventional (i.e., natural); however, within each genus, the species are listed alphabetically. Each species is numbered, and because of the added coverage, the number for any given mollusk in this revised edition will bear no resemblance to the number assigned to the identical mollusk in the first edition. Thus, the many shell collectors who have catalogued their treasures according to the "Myra Keen numbering system" will now be able to spend many pleasurable hours renewing acquaintance while renumbering their collections.

Whereas the first edition could be and often was a constant companion in the field, the present volume is so large and unwieldy as to make its use outside the home or office impractical without cutting in two and rebinding. Even though the sale price would have been correspondingly higher, I feel that the publisher was remiss in not offering it as a two-volume work. Stanford University Press could certainly have divided the volume and had both units bound much more reasonably than the average individual.

As with the first edition, treatment of some groups is still weak, but since those which are weakest are usually the poorest known, these inadequacies are justified in most instances. Generally, this revision will stand as a landmark among molluscan publications, and its "faults" are insignificant compared with its attributes. In reviewing the first edition I noted that "without a doubt, this is the finest single-volume monograph of a molluscan faunal province ever published." At this time I would like to amend that statement to read "second finest"—Myra Keen's newest masterpiece is far and above her first.—*John E. Fitch.*

Fishless Days, Angling Nights

By Sparse Grey Hackle; Crown Publishers, Inc., New York. 1971. 223 p. illustrated. $7.50.

Sparse Grey Hackle (Alfred W. Miller) has collected 23 of his stories, many of which have appeared elsewhere, into a very readable book. It is a book of fishing stories, not fish stories. Most are factual, although in a few instances he has "claimed the right of readjusting the facts to which every angler is entitled". There are stories of fishing trips, companions, camping, tackle and techniques as well as reminiscences of well-known anglers like Hewitt and LaBranche. There is a lengthy chapter on "The Quest for Theodore Gordon". Included are interviews with two friends of Gordon, who is considered to be the father of dry-fly angling in America.

This book will provide several evenings of enjoyable reading. The price is right and the quality is high. Several pages of rare photographs and etchings are included in the book.—*K. A. Hashagen, Jr.*

Life and Death in a Coral Sea

By Jaques-Yves Cousteau with Philippe Diole, Doubleday and Company, Inc., Garden City, New York, 1971; 302 p., illustrated in color and black and white. $8.95

It is the dream of almost every novice diver to one day dive on a coral reef. Jacques Cousteau in this latest book provides previews of what one might expect to experience. However the previews in most cases are entirely too brief.

In this volume Captain Cousteau chronicles the voyage of the *Calypso* to coral reefs of the Red Sea, Seychelles Islands, Maldive Islands, and other areas in the Indian Ocean. The excellent narrative contains descriptions of the sights encountered along the way, both below as well as above the water. But in too many cases my curiosity was left unappeased by a fleeting description of some biological phenomenon.

I feel the book contains too many descriptions of the problems encountered by the ship and crew. This is not to say that this detracted from the story, on the contrary the book is well written, and I found it difficult to put down. My complaint is that more time could have been spent describing the life of the coral reefs, coral biology, and coral identification (including appropriate photographs).

Other faults include inconsistent use of scientific names and italics for same; and some scientific mis-information. Examples of the latter include a statement on page 83 to the effect that the butterfly fish, *Forcipiger longirostris* are "comparatively rare" in my limited experience these fish are one of the more common species of butterfly fish in the tropical Pacific. On page 86 Cousteau mentions a poisonous spine located in the tail of certain members of the scorpion fish family, to my knowledge no members of this family possess such a spine. Finally on page 181 the caption for a photograph of the giant clam (*Tridacna* sp.) states that they are the largest of the mollusks, evidently Cousteau does not consider squids mollusks.

The 122 color plates range from good to excellent. An appendix includes a limited section on diving, coral biology, coral fishes, turtles and an illustrated glossary.

The general reader, particularly divers, will enjoy this book, but I find little in it, other than the photographs, to recommend it to the professional biologist.—*Daniel W. Gotshall.*

Wildlife of Mexico: The Game Birds and Mammals

By A. Starker Leopold. Univ. Calif. Press, Berkeley, Calif. 1972. 581 p. illustrated with photographs and drawings. $18.50.

Wildlife conservationists will be pleased to know *Wildlife in Mexico* is again available. This is a reprinting of the original work published in 1959. This informative and artistically illustrated book would be a welcome addition to any library.—*C. M. Ferrel.*

Round River

From the Journals of Aldo Leopold, edit. by Luna B. Leopold, Oxford Univ. Press, New York, N. Y., 1972, $1.75 paperback.

Aldo Leopold's love of things natural and philosophy are beautifully expressed in selections from the Leopold journals. This is a reprinting of the original work which appeared in 1953.—*C. M. Ferrel.*

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Editor, CALIFORNIA FISH AND GAME
CALIFORNIA DEPARTMENT OF FISH AND GAME
987 JEDSMITH DRIVE, SACRAMENTO, CALIF. 95819

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